THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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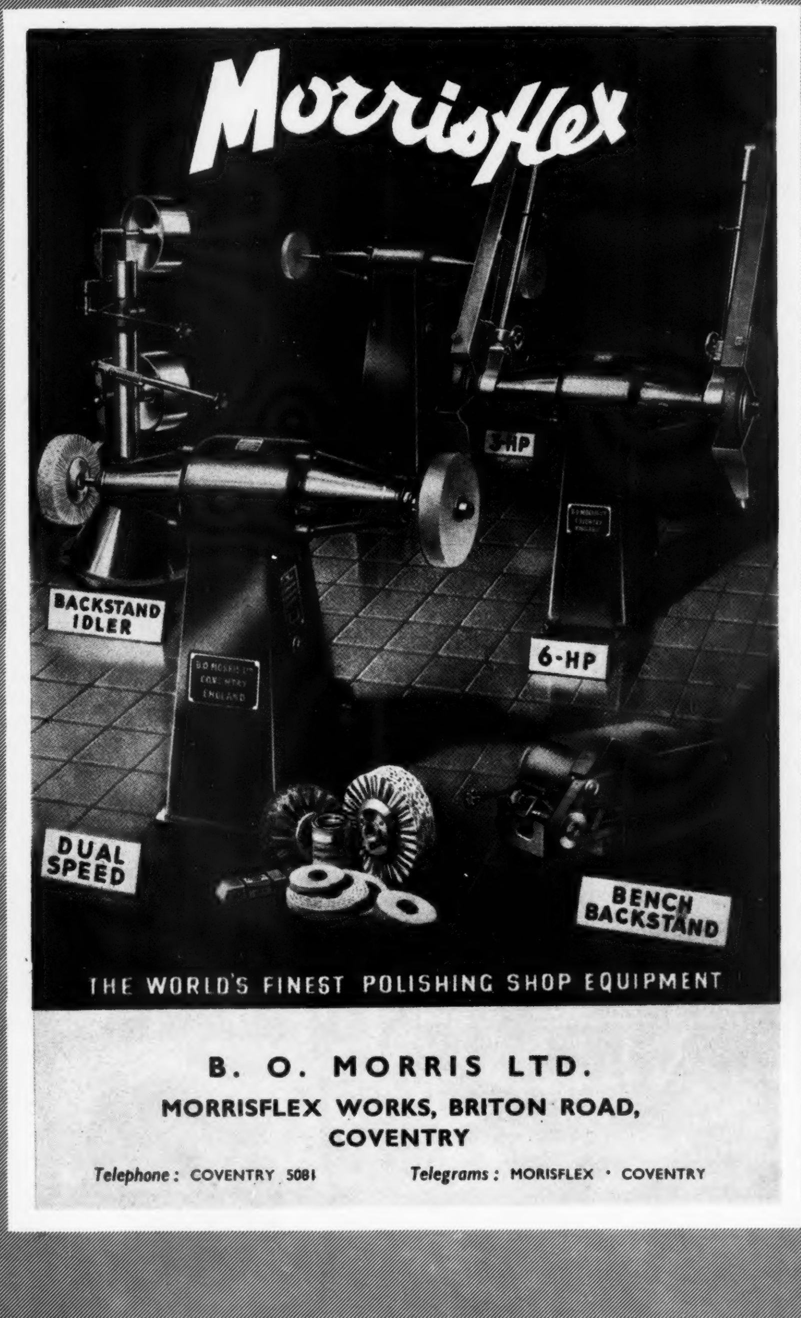
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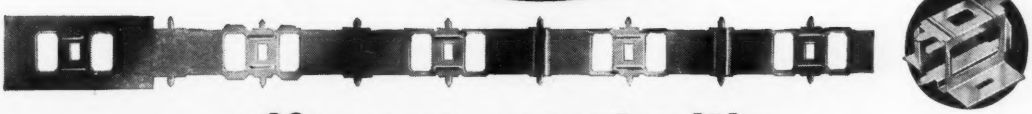

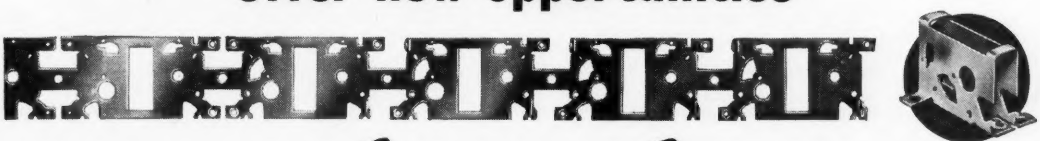

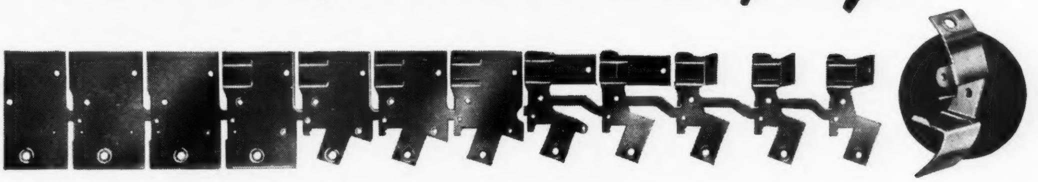


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The Institution of Production Engineers Journal
VOL. 37 No. 5 MAY, 1958

Technical Training and Professional Status

by The Rt. Hon. The Earl of Halsbury,
F.R.I.C., F.Inst.P., M.I.Prod.E.

President of the Institution

IN Britain the law requires the young to remain at school until their sixteenth year. Boys and girls cannot, therefore, leave school until after they have celebrated their fifteenth birthday.

The normal age at which most people are either ready to retire or require to be retired for the good of others is, say, 65. A career-time can thus be regarded as occupying 50 years, and I shall use the words 'educated person' to denote anyone who has devoted part of the 50 years to the purposeful acquisition of knowledge.

In Russia and America young people leave school at a more advanced age but it seems unlikely that they are more scholastically advanced notwithstanding; so that an 'educated person' means approximately the same sort of person to whichever of the great powers he belongs.

Discussions on education disclose that our vocabulary is somewhat inadequate; the English language crystallised out before modern times and has no words for many concepts that we now need to express. We have no simple word, for instance, in which to express an individual's capacity for self-tuition. This is variable and individuals occupy points on a wide spectrum in this respect. Other words that we lack denote individuals who react sympathetically and sensitively either to the spoken word or to the written word, or to pictures, diagrams and models; yet individuals vary widely in their capacity to assimilate knowledge in these different ways.

I have used the words 'purposeful acquisition of knowledge' in my definition of 'educated person' above. It, therefore, rules out of consideration those, and they are many, who have an intuitive ability to 'pick up' what they need as they go along. They are valuable types but according to my definition uneducated types. The word 'uneducated' however bears, in the social as opposed to the technical

meaning, a depreciatory or pejorative sense. To speak of a valuable type in depreciatory terms seem contradictory, as indeed it is unless it is noted carefully that the contradiction stems from an ambiguity in the use of the word 'educated'. Lastly, we have no word to denote the difference between a person who submits himself to an educational curriculum once only, thereafter abandoning further purposeful study, and a person who goes on mixing purposeful study and income-earning work for a protracted period — it may extend throughout a lifetime — after his formal education is complete.

Assuming some sort of a system designed to produce educated persons, to what end does it operate ? What does it educate people for ? One answer to this question is that we do not know. It is easy to say that the Executive Chairman of a big concern needs to know more than a Departmental Manager who in turn needs to know more than a Foreman who in turn needs to know more than an unskilled workman. But how do we know, when they are beginning their education as young people, that as old people they will end up as Chairman, Manager, Foreman or Workman ? And of two Foremen how do we know that one is on the way up the ladder and that the other has reached his limit ? Working up the ladder depends upon a number of qualities being co-present, and educability as judged by the ability to pass examinations measures only one of them.

a practical solution

A practical solution of this difficulty is available if we regard 'education' as intrinsically 'good' ; as having a value of its own, which all seek to establish or at least should be encouraged so to seek. Assuming an open educational system each person would thus acquire the education of which he is intellectually capable on the one hand and, on the other, for the sake of which he is prepared to make some characteristic effort.

We thus commence with the picture of an open system with multiple points of entry, and multiple channels of passage through it inspired by an academic ideal — knowledge as good-in-itself. This ideal finds its highest expression in the University conceived as an autonomous corporate body devoted to learning as an end in itself and awarding various styles of degree to those who have attended its curriculum in one of a selected number of academic disciplines.

difficulty in definition

An academic discipline is difficult to define. Mathematics illustrates one characteristic of a discipline. It is a complete subject. It is, first, a subject. A course in mathematics is all mathematics. There is no poetry or music or history mixed up with it. Secondly, it is complete, as far as it goes. Not complete in the sense that a story is complete, having a beginning, a middle and an end ; but complete in the sense that the surface of the earth is complete. One can travel from point to point in it because every point is connected to every other point in it by some route or other. A degree in mathematics does not mean that one knows the whole of it, or even that the whole is known and available for study, but rather that one has the freedom of it, just as a man with two legs and a map has the freedom of the earth. This freedom to go anywhere does not mean that he has, in fact, been everywhere. By contrast algebra is not a subject; it is a topic. A man who had studied only algebra and knew no geometry, analysis or number theory, would not possess rounded knowledge which gave him freedom.

We can thus regard an academic discipline as a number of topics which, taken together, fit into one another so as to form a rounded whole and convey upon one who studies them a measure of intellectual freedom to think in a particular way. We cannot make a subject out of a number of disconnected topics.

If we take a look at the various subjects in which academic degrees are awarded by Universities we see that some of them are the basis of professional vocations and others are not. Medicine and engineering are studied by those whose intention it is to become doctors and engineers. It is true that some practitioners abandon their profession later — often to become administrators — but the intention behind the degree is practice.

Classics and history are not as a rule read for the purpose of practice, save insofar as practising them means teaching them. It is teaching, however, that constitutes a profession, not the subject taught.

Intermediate between subjects such as history and classics, on the one hand, and medicine and engineering, on the other, lie, for example, law, economics and modern languages. Many read these subjects for their intrinsic interest with no intention of practising them; yet they are the basis of professions which many do practise.

If we turn from the Universities to the professions we find a similar state of overlap. Many professions can be approached by means of a University degree — engineering, for example — while others can not — chartered accountancy, for instance. Typically an accountant must pass the examinations of a professional institute. No equivalent examination terminates an academic degree course in accountancy, for accountancy is not felt to be the basis of an academic discipline. It is a collection of topics more than an integrated subject, topics whose only unifying element is that accountants have to know them for their professional purposes: bits of law, bits of economics, bits of business administration; not the whole law, for example, but partnership law, executorship law, taxation law.

We thus arrive at a picture of professional qualification in relation to University qualification by considering typical cases:

Classics and History ...	Professional only in the academic or scholastic sense, otherwise non-professional.
Economics	Professional, based on University degree only.
Medicine	Professional, based on University degrees. Higher qualifications based on examinations of Professional Institutes, e.g. Royal College of Physicians.
Engineering	Professional, based on either University degree or examinations of Professional Institution, e.g. Institution of Mechanical Engineers.
Accountancy ...	Professional, based only on examinations of qualifying Institute.

history of a professional institution

Consider next the typical history of a professional institution and how its regulations come to take the form they do.

A group of distinguished practitioners, engaged upon activities which are felt to have characteristics which could be the basis of a potential discipline, come together and start an unchartered institution, commonly a company limited by guarantee.

Their object in doing so is to enhance the dignity of their profession by constituting it as such in a form where only approved individuals have the right to describe themselves as qualified practitioners. The professional competence of the individuals is further enhanced by initiating certain educational standards which candidates for admission must possess, the evidence for this being as a rule that the candidate has passed certain examinations, or their exempting equivalents, to a standard set by the institution.

It is obvious that the founder members and the greater part of the first generation of members who are admitted following foundation have themselves never passed such examinations, for the examination system of the institution they founded did not exist at the time of foundation, and there would be little point in subjecting distinguished practitioners of a subject to examination in the terminal stages of their careers. This historical situation is invariably perpetuated in the power of the Council to admit to full Membership anyone who has achieved distinction in the professional field concerned.

The examination system is intimately linked to a second conception, that of Associate membership. Associate membership is concerned with the grant of professional status to individuals in a younger age group. At an age when they could not hope to claim distinction or maturity by virtue of achievements for which they have had no time, they are nevertheless offered professional status as an incentive to subject themselves to the examination system. This serves the double purpose of attracting recruits to the profession and advancing its educational standards by securing that a steadily increasing proportion of members have, in the early stages of their career, qualified by passing examinations.

It follows that to excuse a candidate for *Associate* membership from the need to subject himself to the test of an examination or its exempting equivalent would be a contradiction in terms. A candidate for *Associate* membership is essentially a person who does *not* regard himself as a candidate for membership by virtue of distinction or maturity as a result of achievement or experience. He must by definition be a person who has no confidence that he would be acclaimed by his fellow practitioners as a distinguished equal.

an element of hardship

The foregoing argument has one element of hardship in it if exclusion from membership be regarded as a hardship. Associate membership is concerned with an examination-passing age group beginning around the age of 25, say, while experience, maturity and distinction set in at around the age of 45.

It is clear that men aged about 35 fall half-way between these groups and to require of all men in such an age group that they should pass an examination would involve hardship for some in view of personal circumstances. There would accordingly be for some men in the 35 age group a mere choice of hardships — exclusion from professional status on the one hand, or subjection to a domestic upheaval on the other.

In such cases it is common practice for Councils of professional institutions to require of candidates that they should write a thesis on a subject chosen so that their experience and ability to assimilate fundamentals will have a chance of manifesting itself in a specialised field. The justification for this procedure is simple. By comparison with the 25 age group the career pattern of a 35 year old man is no longer plastic. The question of training him for general purposes cannot arise, for he will already have been trained to specialise, and if his knowledge of the fundamentals involved in a specialised field of experience has been derived from self-tuition, it would be *prima facie* evidence of a right-minded approach to professional work which would presumably manifest itself in the context of any other specialism in which the individual involved himself at a later stage.

We thus arrive at the following criterion for admission to corporate status :-

Members :	1. In virtue of experience, maturity and distinction; 2. By transfer from the Associate membership according to rule.
Associate members :	3. By examination; 4. By exemption; 5. By thesis.

Now my purpose in setting out all these matters is not to make an abstract study of one aspect of social life, but rather to establish the facts as a prelude to some thinking about the subject of production engineering.

an important distinction

First, however, let me deal with a distinction of some importance and one which only occurs in the context of the scientific and technological professions, namely, that between a professional institution and a learned society.

It is well illustrated by two bodies to each of which I belong, the Chemical Society and the Royal Institute of Chemistry. The Chemical Society is a learned society. Its monthly publication, the Journal of the Chemical Society, contains the current month's output of results from every active group of chemical research workers in the country and circulates widely throughout industry and the universities. Its membership is an open one; an interest in chemistry and the willingness and ability to pay the annual subscription are the only criteria for membership.

The Royal Institute of Chemistry is a professional body. Its concern is educational standards in the profession of chemistry, standards of professional behaviour and the interests of its members in the professional sense. Its Journal is concerned with its own affairs and technical articles therein are more of the character of general essays on interesting topics rather than the latest output from the laboratories. Admission to its fellowship is direct, based upon eminence, or by transfer from the Associateship. Admission to the Associateship is by examination, exemption or thesis.

In the world of engineering, learned societies have not taken root and flourished as they have in the world of science. There are local engineering societies, it is true, but there is no national society which does for engineering what the Chemical Society does for chemistry. Possibly this reflects a real difference between the two disciplines. Tens of thousands of new chemical substances are synthesised every year and new reactions are to be numbered by the hundred. A means of recording and publishing the properties of these substances is an intrinsic requirement. In terms of monthly results chemistry is prolific of records requiring publication in a way that engineering is not. The journals of the professional engineering institutions have accordingly become the normal vehicle for publishing results of academic interest to the professions concerned, while alongside them flourish a range of periodicals on technological subjects published for profit and varying widely in merit; some of them appear to be little more than devices for distributing advertising matter.

The Institution of Production Engineers

With this much preamble let us consider our own Institution, The Institution of Production Engineers.

It is characteristic of any self-perpetuating tradition that it tends to get into a rut without knowing it. The mature phase of mechanical engineering which was achieved in the 19th century would have been regarded as of an entirely general character by any of its practitioners. In fact, it developed a trend towards the over-emphasis of design engineering and neglected the revolution in production techniques that Henry Ford originated in the automobile industry, and the consequent increase in importance of such subjects as engineering metrology which resulted from it. By the end of World War I the need to professionalise production engineering could have been met either by the existing professional bodies taking an active interest in the subject, or by the formation of a new professional institution. The second alternative came to pass and the founders of The Institution of Production Engineers held their first meeting on 26th February, 1921. Many of these founders were themselves professional engineers and well aware of the implications of what they were doing. Their decision was taken in order to :-

(a) establish the status and designation of a production or manufacturing engineer;

(b) promote the science of practical production in any branch of industry, and to give impulse to methods of production likely to be an asset to members of the Institution and the community;

(c) enable engineers, manufacturers and specialists who are engaged in productive effort of any kind to meet, to discuss, to correspond and generally to facilitate the interchange of ideas appertaining to the science and practice of manufacture.

The membership was determined by election in the early phase. Practical training and experience were the criteria and no academic demands were made on candidates. The need for this was soon felt, however, as younger age groups increasingly sought admission, and 11 years after the formation of the Institution the first examinations were introduced. These evolved through the years, becoming progressively more stringent, culminating in 1951 in the introduction of the Institution's compulsory Part III dealing with managerial topics. Statistics of the membership at 30th November, 1957, are given in Table I, and indicate that approximately three-quarters of the professional grade members, corporate and non-corporate, are now in possession of professional qualifications. These figures reflect the fact that the terminal phase has now been reached in which the regulations for admission conform exactly to the model described above; a Higher National Certificate or University degree provides an exempting equivalent to Parts I and II of the Institution's examinations, which themselves rank subject by subject as exempting from the examinations of the Institution of Mechanical Engineers. If this had been the whole story, the history of our Institution would have differed in no way from that of others.

Table I

ANALYSIS OF THE INSTITUTION OF PRODUCTION ENGINEERS MEMBERSHIP RECORDS AT 30th NOVEMBER, 1957

An analysis of the membership records of The Institution of Production Engineers was made at 30th November, 1957, to determine the proportion of the membership who were academically qualified. An academic qualification, for the purposes of the survey, was taken as:-

(a) A University Degree.
(b) I.P.E. Exams. or thesis.
(c) Corporate membership of a Chartered Engineering Institution.
(d) Higher National Diploma or Certificate.
(e) For men trained before 1921 (i.e. pre-Fisher Act) a three year full-time, or five year part-time course at a recognised technical college.

The result of the analysis is tabulated below:-

Grade of Member	*Total No. in Grade*	*Academically qualified*		*Remarks*
		Yes	*No*	
Hon. Members ...	6	6	—	
Members ...	1,715	1,114	601	
Associate Members	5,173	3,400	1,773	
Associates (non-corporate)	148	148		Associates are men qualified in another profession whose work is ancillary to production, e.g. Cost Accountants or Metallurgists.
Graduates (non-corporate)	2,240	2,240		
TOTAL *qualified grades*	9,282=100%	6,908=74.4%	2,374=25.6%	
Students ...	1,088		1,088	All following an approved course of academic study and practical training.
Affiliated Organisations	259		259	Corporate bodies desirous of subscribing to the object of the Institution.
TOTAL *all grades*	10,629	6,908	3,721	

The special characteristic of production engineering, however, is that it is difficult to define in precise terms, particularly in terms which would give it the status of an academic discipline. Regarded narrowly it is but a single topic, metal-working, dominated by machine tool technology — a legitimate topic and a genuine one but too narrow to be the basis of an academic discipline, on the one hand, or of a professional institution on the other. Regarded more broadly it is a collection of topics so heterogeneous that it has no underlying unity. As soon as the bounds of the machine shop are passed and the frontiers of 'manufacture' crossed, what is encountered? Is the manufacture of bread 'production engineering' and, if so, what has it in common with the machine shop?

In 1946 and 1947 continuous discussion took place in the Council with a view to broadening the basis of membership and the difficulties of doing so were found to be so severe that 11 years later, in 1958, it is not possible to say more than that discussions continue.

The word 'engineering' is used in two ways. There is first the technical meaning associated with industry and the professions. In this sense a production engineer is an engineer concerned with production. An older meaning of the word 'engineering' is to be found in an alternative usage, as when we talk of 'engineering a meeting between two parties' or 'engineering an agreement' between them. In this sense a production engineer is one who 'engineers' (in the sense of 'arranges' or 'manages') production. It seems to many that it would be a disingenuous use of the word 'engineering' in the context of 'production engineering' to claim, on the one hand, that it was used in the sense of 'arranging' or 'managing' and, on the other hand, to examine candidates for membership in engineering subjects using the word 'engineering' in its modern technological sense.

It seems to many others that to use this as an argument for confining 'production engineering' to the machine shop and the press shop is to reduce it to a mere topic in the field of general engineering and to rob its practitioners of any claim to professional status. No such narrow intention was discernible in the manifesto of the founders.

broadening the basis

If it was universally desired to broaden the basis, then it would be possible to list certain steps which would be feasible and others which would not.

An 'Institution of Production Technologists' would have such a broadened basis. The qualifying conditions for Associate membership could be:

(i) A University degree — or the exempting equivalent — in physics, chemistry or any engineering technology.

(ii) Part III of the Institution's examinations.

(iii) A responsible position on the technical side of manufacture.

If, in fact, 80% of the membership of such an Institution were concerned with 'mechanical engineering production', then the Institution could for convenience arrange its own examinations in 'Engineering', indistinguishable from the present Part I and II of The Institution of Production Engineers. It could not, however, describe itself as an Institution of Production *Engineers*. It would embody the spirit and the wording of the founders' manifesto, but would have to sacrifice their choice of title. To many this sacrifice appears unacceptable.

What is *not* feasible, if the Institution is to retain its claims to professional status, is to confuse 'broadening of the basis' with 'relaxation of the standard' by confusing 'Membership' and 'Associate Membership'. Associate Membership is not an *inferior* grade of membership. It is a *youthful* grade of membership and the possibility of admission thereto provides young people with an incentive to submit to examinations based on study. The argument that a young candidate without academic qualifications, but with experience in some branch of manufacture, should be admitted to Associate Membership without examination is a fallacious

one; it presupposes a contradiction in terms. It makes a further confusion between the status of and qualifications for admission to a learned society and a professional institution. By all means let 'good production men' come to the meetings of the Institution as guests. But by every means exclude them from Associate Membership unless they comply with both the spirit and letter of the regulations.

Such are the choices which members of the Institution must make. Until some choice emerges, as representing the overriding views of its members, the Institution must remain undecided between being or becoming :

(i) A *Society* of Production Engineers;

(ii) An Institution of Production *Engineers;*

(iii) An Institution of Production *Technologists.*

Assuming that (i) and (iii) are rejected, for the time being at any rate, what attitude would best reflect the intention of the founders ? How can a set of topics be welded into a discipline ?

One possible approach would be to bring some philosophy to bear upon the various topics that constitute production engineering, establishing each upon as sound an intellectual footing as possible.

Consider, for example, 'materials handling' as a subject. It can be approached in two entirely different spirits. The first approach could be illustrated by whatever would be involved in memorising a catalogue of all available types of fork lift truck with their respective performances, costs and savings. No such approach would ever convert the information in the catalogue into a higher form. Hard facts do not acquire an intellectual flavour by being memorised, and since twice nothing is still nothing, nothing can come of adding to the details of fork lift trucks further details of belt conveyors and telpherage systems. Materials handling can never become a 'subject' by treatment in this way.

The second method of approach would treat the subject in a spirit of enquiry. Every method of handling involves a traffic problem entailing random arrivals and departures, congestion, queues and on-peak and off-peak loads. Every technical device is an investment intended to produce a return by means of an economy. How is it to be calculated, absolutely, marginally and after tax ? How does the return depend on the technicalities of utilisation based on loading ? Lastly, how do different devices, e.g. continuous systems such as belt conveyors, and unit systems such as fork lift trucks, differ from one another in respect of return as a function of utilisation ?

This second treatment based on fact, economics and operational analysis would be an intellectual treatment. The man who could master and apply it would be a production engineer in the best sense of the word, in no way to be confused with the designer or operator of materials handling devices.

The Institution has recently initiated a study group based on problems of materials handling. It is early days to say how the project will work out. If it approaches the subject in the right spirit, however, it will bring intellectual order out of the chaos of the catalogue and yet another topic will have been added to its list of subjects dominated and understood.

the true function of the production engineer

Manufacturing technology does not advance in terms of discovery in the same way that Science advances by discovering the laws of Nature. Its advances are empirical and unpredictable; they depend upon the necessity which mothers invention, and the ingenuity of inventors that fathers it. From time to time a group of independent techniques can be seen to possess that something-in-common by virtue of which they are grouped. Intellectual attack upon the nature of this common factor should be the true function of the production engineer.

Mechanical engineering has had to follow the same course. Early steam engines were never designed from scientifically understood first principles in the way that early nuclear reactors were designed from first principles. Various prime

movers were designed by eye and worked — more or less. The common factor was discoverable in that they all employed steam. Steam engineering came into existence as an intellectually honest attempt to rationalise the *modus operandi* of all steam engines. Mechanical engineering is a collection of topics such as steam engineering. To steam engineering we can add stress analysis, the theory of structure, the theory of machines and so on. They have sufficient in common with one another to form a true subject when collected together.

On this view, production engineering differs from mechanical engineering, not in spirit, but in being younger. The number of topics which have been dominated and reduced to intellectual good order is smaller, so that they do not as yet form a broadly based subject on which a university degree can be awarded. Time and patience seem to be what are most called for in these circumstances.

There are other topics, however, where common factors are discernible and out of which a dispassionate student could seek to extract a philosophy and a discipline.

When handling extremely dangerous or poisonous substances such as radioactive fission products, nerve gases or bacterial toxins, the techniques of handling must be such that nothing escapes into the ambient. Alternatively, when handling spontaneously inflammable materials such as the hydrides of boron or silicon, the ambient must never come in contact with the material handled.

Techniques of remote control appropriate to the above circumstances have belonged, so far, to chemical engineering rather than production engineering.

It is becoming increasingly clear, however, that the manufacture of fast transistors to anything like a tight specification will turn upon a similar technique.

As you know, transistors are made by adding to the semi-conducting elements in Group IV of the Chemist's Periodic Table (germanium or silicon) minute traces of impurities represented by elements in either Group III (aluminium, boron, indium) or Group V (arsenic, antimony). The germanium and silicon have to be prepared first in an almost unbelievably pure state and controlled quantities, fractions of a part per million perhaps, of the impurities added. Minute slices of these materials have then to be assembled sandwich-wise after various processes of fusing and etching.

The product is a small piece of electronic jewellery and is very variable in performance. After manufacture, the individual transistors are screened for performance and batched up in very variable quantities for marketing under widely different specifications. One manufacturer recently transferred production to a new factory only to find that a specification hitherto producible without undue difficulty could no longer be reached. The reason ? Unknown !

importance of cleanliness in manufacture

Increasingly it is becoming clear that we dirty humans cannot be allowed near transistors while they are in process of manufacture. How then are they to be produced ? The answer is to be found in a marriage of remote control technique to the technique of the transfer line. Transistors are already being made automatically under hermetically sealed conditions of manufacture with all that involves in the way of stagewise instrumentalised inspection and rejection, station by station along the transfer line.

Manufacture under conditions of surgical cleanliness is not entirely new. When the gramophone record industry made the transition from the short playing record with 100 grooves per inch to the long playing record with 250 grooves per inch, technologists soon found that revolutionary standards of cleanliness were required if the level of the background noise was not to rise to an objectionable pitch.

Production of capital goods for the nuclear power industry requires a similar philosophy, as was made clear during the course of a conference recently organised by the Lincoln Section of the Institution.

There is thus a group of techniques which could be welded into a topic by anyone with the requisite insight. It belongs with automatic assembly, as in the automatic assembly of amplifiers, time bases, and so on, in the electronic industry.

Printed circuit boards are held under successive stations and components are automatically stapled to them, prior to dip soldering and assembly of the whole into a single electronic circuit. The topic awaits its theorist, its systematiser.

A lady once remarked to Karl Friedrich Gauss, the great mathematician and physicist, that it must be wonderful to make the sort of discoveries that he did. "As to that, Madam", he is said to have replied, "it is necessary first to reflect deeply on the subject matter".

Automatic assembly, surgically clean manufacture, hermetically sealed operations: these are techniques which await the genius who will reflect deeply about them and give them intellectual unity.

You can see, however, that a number of topics, each of which belongs to production engineering, are beginning to mature. Cutting and shaping, materials handling, automatic assembly (as above), and industrial mathematics (which stands to production engineering as stress analysis stands to design engineering) are four topics which could form the nucleus of a degree course.

Study of the production engineering courses at our universities and colleges of higher technology soon discloses that the time for unifying these topics into a subject has not yet matured, either absolutely or in the minds of those responsible for teaching.

There are 56 technical colleges in which a Higher National Certificate in Production Engineering can be obtained, and there are four colleges of higher technology which have announced the granting of Dip.Techs., namely, Loughborough, Birmingham, Cardiff and Northampton. The equivalent of a university degree in production engineering will be awarded in due course by the College of Science and Technology in Manchester, but the setting up of the department concerned was only announced during the course of the last academic year and a few years must elapse before any graduates issue with degrees. The course in light engineering at Imperial College of Science and Technology seems to include a great deal of what we would regard as production engineering, but the foregoing list comprises all who are attempting to give an integrated presentation of the subject, and only one of these amounts to a degree in production engineering.

There are one or two postgraduate courses of a general character, notably one each at Durham and Cranfield, the Cranfield course having somewhat of a bias towards the rationalisation of automatic assembly techniques. Glasgow and Cambridge afford facilities for somewhat intenser study of machine shop practice and metrology than the average. Finally, there is a group of universities which provide courses covering part or all of the curriculum required for Part III of the Institution's examinations, namely, Birmingham, Nottingham, Edinburgh, Leeds, Sheffield and the College of Science and Technology in Manchester. One has to concede, however, that single courses in production engineering giving an integrated treatment of the whole subject on academic lines, at the level of an honours degree, are still few and far between.

The destiny of The Institution of Production Engineers must be to act as the focus of all working attempts to give unity to this subject. There can be no degree course until the Institution has shown how such courses ought to be constructed. It must pioneer as The Institution of Mechanical Engineers pioneered and the degree course will follow when the time is ripe.

a worthwhile struggle

Why is the struggle worth while? It is worth while not because a group of people want recognition as an independent profession, but for a very different reason.

"All power tends to corrupt. Absolute power corrupts absolutely." This was the conclusion of an Anglo-German historian, Lord Acton, who spent his career in collecting the materials for a great work on human freedom which he never lived long enough to publish. His industrious systematism was typically German; his

conclusion was typically English. Freedom in his view depended not on an abstract theory, but upon a critical balance of forces achieved rarely but most typically in Britain. Crown, Privy Council, Cabinet, Lords, Commons, Church, Municipalities, Universities : each of these has a limited measure of power conceded and supported by all the others. Any encroachment by one upon the field of another is resisted by all. The result is a marvellous balance of a type which social anthropologists are only now beginning to understand fully. It leads to stability and continuity of a type rare in human history. The French parted company with their past in 1789 and the Russians in 1917. The United States acquired a present in 1776, the German and Italians in 1870. The immemorial continuity of our own history stretches back 1,000 years; five times as long as the oldest of our competitors. But the marvellous balance of our society is often in jeopardy for one reason or another notwithstanding. Our concern is to preserve it. One danger could come from the virtual monopoly Universities would possess were there no alternative source of education. The professional institutions of this country provide just such an alternative and the well-being of the nation's technological life depends in part upon the healthy competition which the institutions present to the Universities. It is good that professors dwelling in ivory towers should reflect deeply upon a subject and conclude, " Thus shall it be taught ". It is good also that practical men, finding time amidst the rough and tumble of their affairs to attend to the requirements of their profession, should meet around the conference table and conclude, " Not thus, but so! ". It is good too that the conclusions of each should compete with one another for the registration of students, until in the fullness of time they approach one another's outlook and thereafter hold one another in balance : dancing partners rather than rivals.

If engineering as conceived by the Universities, as conceived for the Dip.Tech. and the H.N.C., as conceived by the institutions of professional engineers, mechanical, electrical, civil and aeronautical, is not to ossify, it must meet the challenge of new professions starting as splinter groups and either evolving into maturity or decaying into evanescence. To such a challenge this Institution of Production Engineers is dedicated. If production engineering ever becomes the subject of a degree course it will be because this Institution made it one. If out of the bewildering variety of techniques involved in manufacture, intellectual good order and discipline can be extracted topic by topic, and if from a variety of topics a subject and a discipline can be made to emerge it will be because the members of this Institution struggled so to resolve the issues before them. And if the members of this Institution so strive, it will be because a small group of pioneers launched them on the way in unspectacular but nonetheless determined fashion, to wit, by convening a meeting at the Cannon Street Hotel, London, on Saturday, 26th February, 1921.

Great oaks from little acorns grow.

A new approach to

PRODUCTION CONTROL

by J. L. Burbidge, A.M.I.Prod.E., A.M.B.I.M.

Born in Toronto, Canada, Mr. Burbidge was educated in New York, and later at Wellington School, Somerset, and Cambridge University.

He entered industry as a student apprentice with the Bristol Aeroplane Company) (Aero-Engine Division) and has since worked for both Blackstone & Co. Ltd. and R. A. Lister & Co. Ltd. in the R. A. Lister group of companies; for the Ministry of Supply (A.P.1e); for the R.A.F.; for Harrison McGregor & Guest Ltd.; and for David Brown Industries Ltd.

Mr. Burbidge has had an exceptionally wide experience of management, holding at various times the posts of Shop Manager; Department Manager; Chief Inspector; Commanding Officer of a number of R.A.F. Engine Repair Squadrons in the Middle East; Chief Planner; Sales Manager; Assistant to Managing Director; and General Manager. He approaches Production Control, therefore, more from the point of view of general management than as a specialist.

His specialised experience, however, has included two assignments during which he assisted at the installation of new Production Control systems by different firms of consulting engineers, and the post of Chief Planner (in charge of production planning and control) for Blackstone & Co. Ltd.

Mr. Burbidge is the author of " Standard Batch Control " — describing a new system of Production Control — and his second book on the subject is being prepared for publication.

1. introduction

Production Control is the weak link in the engineering industry today.

Bad Production Control is responsible for the majority of failures in the industry. It is responsible for an enormous loss each year through obsolescence. It is responsible for tying-up in stocks, vast sums of capital which could be better employed on development. It is responsible for a fiscal policy, which uses capital far below its potential profit earning capacity.

You may not agree with all of this, but I think you will agree that in the engineering industry today, Production Control *is* the weak link.

2. why is it the weak link ?

In this Paper I propose to give my diagnosis of the cause of the present weakness in Production Control and to suggest a possible cure.

My remarks are confined to batch production in the engineering assembly industry, because this is the industry which I know best. I believe, however, that the same principles apply to many other industries as well.

In my opinion, most of our troubles with Production Control today can be attributed to the acceptance of two false theorems and, as this is not a detective story, I can reveal the " villains " of the piece right away. They are :-

1. the theorem of the "economic batch quantity"; and
2. the theorem that " minimum costs " lead to " maximum profits ".

(a) *the theorem of the economic batch quantity*

This states that for each separate part made in a factory and for any given set of conditions, there is

one and only one batch quantity for manufacture, or for purchase deliveries, which will give minimum costs.

This quantity can be calculated by a number of different methods, but the theorem is one of those in which most people believe, but which is seldom put into full practice. Very few firms, either here or in America, actually calculate the quantities.

This is a pity because it is only when you try to calculate the quantities that you find out what a silly idea it really is.

I repeat, however, that although very few firms bother to calculate the quantities, the theorem is almost universally accepted. You have only to remember the number of times you have heard remarks such as the following — and perhaps agreed with them — to know that this is true:

"You surely don't expect me to set up a hammer for a batch of 25."

"It doesn't pay to run these moulding machines for less than a day at one set-up."

"It doesn't cost any more to make 2,000 than 200 on this machine, once it's set up."

The theorem is believed, but the quantities are usually guessed. I submit first that, if output is constant, changes in batch size have an insignificant effect on costs and, second, that the theorem of the economic batch quantity is completely false, when it is applied to the individual components of an assembled product.

(b) *the theorem that minimum cost gives maximum profit*

This is the theorem which puts the "economic" into the "economic batch quantity", because obviously if the "EBQ" is the quantity for minimum cost and maximum profit occurs when costs are at a minimum, then this quantity is the "*economic*" quantity.

I submit that this theorem is also false. Like the theorems of the past that "the world is flat" and that "the sun revolves round the earth", it is seemingly obvious, but nevertheless absolutely untrue. Provided that the cost price structure is such, and that at least some margin of profit is earned, then a policy of sub-optimisation for minimum cost will generally reduce company profits far below their possible optimum.

3. the case against the "economic batch quantity"

(a) *the combined cost curve (traditional)*

The "combined cost curve" shown in Fig. 1 is a synthesis of a number of similar illustrations which appear in textbooks on industrial administration, economics and production control.

Generations of engineers have seen this illustration and have learnt the apparent lesson, that cost varies greatly with batch size.

There are three curves on this graph: first, a line showing how "preparation costs" vary with batch size; second, a line showing how "carrying costs", or storage and financial costs, vary with batch size; and finally, a line showing the combined effect of these two variables. You will note that there is a nice conspicuous *minimum* on the combined curve, which is supposed to indicate the batch size for minimum cost.

Most engineers have seen a curve like this before, but I wonder how many have seen a real combined cost curve — the curve for an actual part made in a real factory. Such a curve is shown in Fig. 2.

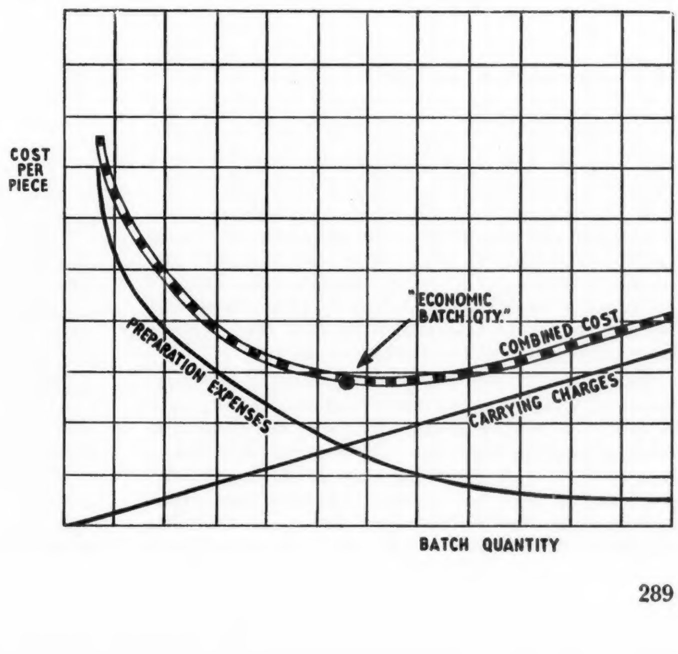
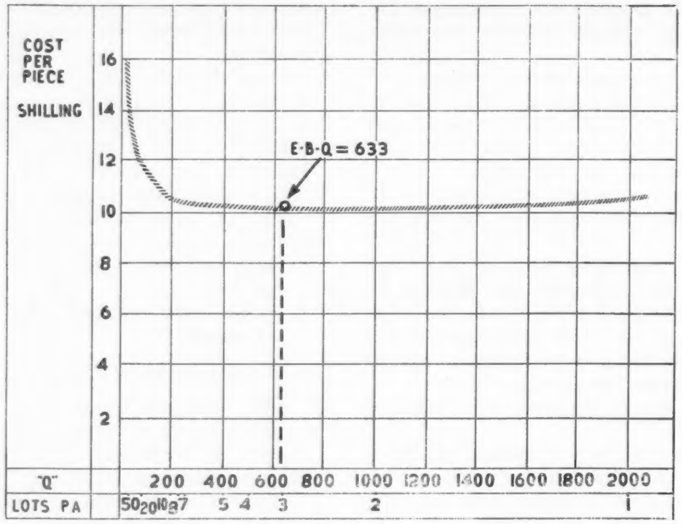


Fig. 1. Combined Cost Curve (traditional)



No. of Lots P.A.	1	2	3	4	5	6	7	8	10	20	30	50	100
Q	2,000	1,000	666	500	400	333	285	250	200	100	67	40	20
Set Up Cost P.A.	100	200	300	400	500	600	700	800	1,000	2,000	3,000	5,000	10,000
Carrying Cost P.A.	1,000	500	330	250	200	166	143	125	100	50	34	20	10
Total Cost of 2,000	21,100	20,700	20,630	20,650	20,700	20,766	20,843	20,925	21,100	22,050	23,034	25,020	30,010
Cost Per Piece S/	10.5	10.35	10.31	10.33	10.35	10.38	10.42	10.46	10.56	11.0	11.5	12.5	15

Fig. 2. The Combined Cost Curve (including Direct Costs and Fixed Overheads)

(b) *a combined cost curve (actual)*

You will observe first of all that the curve has shot up towards the top of the sheet. The gentlemen who drew the first curve had forgotten to show the direct costs and that large body of fixed expenses concerned with neither "preparation" nor "carrying".

You will observe, further, that the curve itself is an anaemic flat-chested affair. You can still find the EBQ, or minimum, but it doesn't look half as impressive as it did in Fig. 1, because preparation and carrying costs are now shown in their true proportions, as only a small part of total costs.

There is still one thing wrong with this curve, however. In making it I have used *total* preparation expenses and *total* carrying charges in the usual way recommended in textbooks, but this must be wrong, because in these enlightened days of the break-even chart and of marginal costing, everybody knows that expenses can be divided into *fixed* and *variable* categories.

(c) *variable expenses*

When, for marginal costing, we study the variation of different expense items in relation to changes in output, we find that a part of each expense is usually *fixed*, or independent of output, and that the remainder varies in some direct relationship with changes in output level.

This is not, however, an exclusive peculiarity of changes of expense in relation to output. A similar effect occurs when we investigate changes of expense in relation to other factors as well. In particular, this effect is very noticeable when we examine the variation of expenses in relation to changes in batch size.

Here, we are interested in the effect of changes in batch size on cost per piece and the only expenses that can possibly be of use in our calculations, are those which vary with changes in batch size.

An investigation of the preparation expenses and carrying costs in industry, leads to the conclusion that these expenses are mainly *fixed* and that only a small part is variable with batch size.

To illustrate this contention we will now consider one item of expense from each of these two main categories.

(d) *variability of setting expense*

First, let us consider "setting expense". When we use a formula, such as Camp's formula, to calculate the *Economic* Batch Quantity, we make the assumption that there is a fixed or standard cost for setting-up and that doubling the number of batches will double the amount of setting-up expense.

But — and here is the big snag — if setting-up expense were directly proportional to the number of batches, then halving all the batch sizes in a works (without reducing total output) would double the incidence of total setting-up expense. Most experienced managers know that this just does not happen.

I know myself, from direct experience of a case where all batch sizes were halved in a works, in an overstocking emergency, and there was no increase in setting expenses whatsoever.

I believe that there are a great many reasons for this phenomenon and here I will give five of them :-

1. The labour cost component in setting-up can only be reduced effectively in units of one setter's wage. In a small shop, therefore, with only one or two setters, the labour component of setting-up will be mainly a *fixed* expense.

   Fixing piecework rates for setting-up does not change the situation. A setter on piecework may earn £16 in a busy week. If in the next week he only has one quarter as many set-ups to do, he doesn't then take home £4. Due to the effect of the minimum wage and the necessity to conserve skilled labour, in all probability he will suffer little, if any, reduction.

   Making the operators set their own machines doesn't alter the situation either. If they do this work, they are re-rated as skilled men and the additional pay is, in reality, part of the *fixed* setting expenses.

2. If any shop where batch quantities are large, there will usually have to be a number of breakdowns, due to shortages or rush jobs.

   Reducing "nominal batch size", in these cases, will not increase setting-up expense in direct proportion to the number of batches made. In the case from my own experience mentioned earlier, in which all batch sizes were halved without increasing setting expense, I believe that one of the main things we did was to reduce the "nominal" machining batch size to the "actual" machining batch size.

   We made a big reduction in the delivery batch size for purchased materials and, therefore, on the average inventory, but very little reduction in the machining batch size, because this had already been reduced, in effect, by the large number of split batches necessary to keep an even flow of parts to assembly.

3. The third explanation I would offer for this phenomenon that total setting expense does not vary directly with the number of batches, is that a reduction in batch size may tend to increase "setting-up" expense, but it will also tend to reduce "re-setting" expense.

4. Again, a set-up which is used once a month will normally take less time per set-up, than one which is used only once a year. For this reason again, set-up time per batch tends to fall as batch sizes are reduced.

5. Finally, we must consider sequence of loading. Consider a capstan lathe, set-up for a job made from ½ in. brass bar. If the next job is similar in shape and also from ½ in. brass bar, setting-up may take five minutes. If, however, the next job is from hexagon steel bar, involving a change of collett, cleaning out the sump, changing the coolant, fitting a new knee tool holder and so on, the setting-up may take two hours, or 24 times as long.

   Apart from demonstrating the essential inaccuracy of the assumption that there is a fixed setting-up time per batch, this example is important because it is easier to schedule smaller batches to take advantage of this possible saving, than it is to schedule large batches to the same end.

   Once again set-up time per batch tends to fall as batch sizes are reduced.

It will be seen that in all these five examples, there are factors at work which tend to maintain setting-up expense at a fixed sum per factory, for any given level of output. We can in fact best describe the variability of setting expense in relation to changes in batch size, by stating that a large part of this expense is *fixed* and only a small part is *variable* with changes in batch size.

(e) *variability of storage charges*

As our second example of variability we will consider storage charges. It is difficult to find any variable content at all in this item of expense, with respect to changes in batch size. Provided that the output rate is constant, the charges for maintaining, heating, lighting, manning and supervising the stores, will be approximately the same whatever the batch size. What is more, any small variability that does exist will probably work in the reverse direction to that normally expected. Storage expenses will tend to get slightly larger as batch sizes are reduced, due to the greater number of transactions involved.

It is very easy in industry to confuse the true variability of an expense, with its apparent variability due to the method of overhead allocation used in costing. The fact that we recover expenses by an overhead rate on direct labour, for example, does not mean that expenses are all directly variable with direct labour. Nor, if one changed overnight to a new system of allocation based on direct material, would that mean that all overhead expenses had suddenly ceased to be related in any way to direct labour cost.

The fact that it is sometimes convenient to divide total storage costs by total output, to get average

cost rates of "storage cost per piece", does not mean that storage costs will increase directly with an increase in batch size and the consequent increase in the size of the stock inventory.

Once again, the best way to describe the variability of storage charges in relation to changes in batch size is to say that this expense is mainly *fixed* and only a very small part is *variable* (inversely) with changes in batch size.

We have considered only two items from those which together comprise the preparation and carrying expenses. Very similar results are obtained with most of the other expense items involved.

(f) *combined cost curve using only variable expenses*

I hope I have said enough to show that even Fig. 2 is a highly exaggerated picture of the effect of batch size on cost, in the case of the particular part concerned.

If we now redraw the curve using only the variable expenses, we get the result shown in Fig. 3. The curve is now so flat that it is difficult to see the *minimum* with the naked eye.

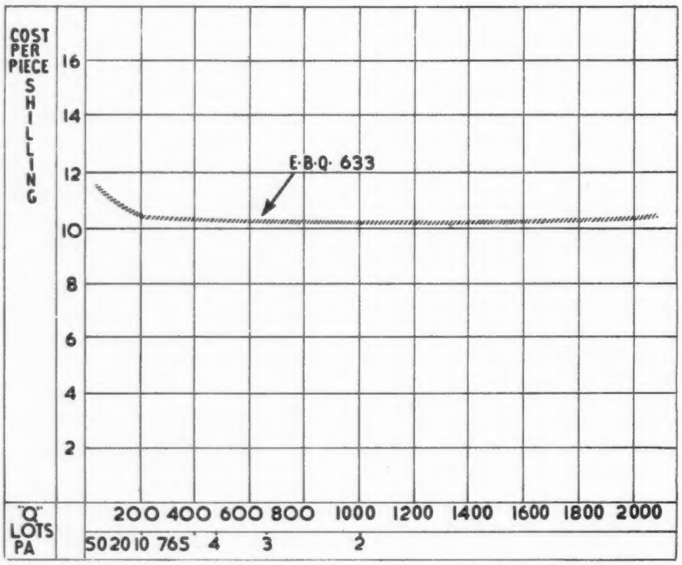
We find also that batch size has a negligible effect, in this case, on cost per piece.

(g) *conclusions*

Although I cannot prove it in the space available, I am going to postulate that the curve in Fig. 3 is far more typical of the actual effect of batch size on cost, in industrial batch production, than is either Fig. 1 or Fig. 2.

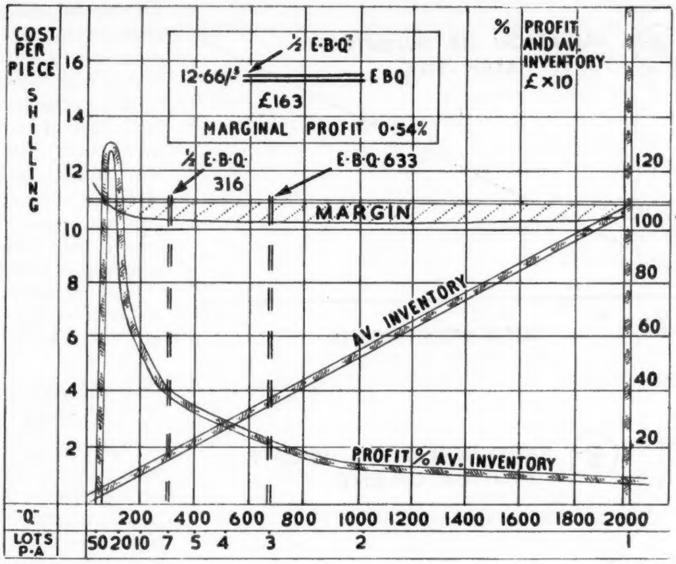
If I am right, and costs do in fact vary very little with batch size, two very awkward questions arise :-

1. where now is the justification for the complicated and expensive control procedures, needed to control production, when all parts are controlled individually in their own special batch quantities ?



No. of Lots P.A.	1	2	3	4	5	6	7	8	10	20	30	50	100
Q	2,000	1,000	666	500	400	333	285	250	200	100	67	40	20
Fixed Pre. & Car. Exp.	500	500	500	500	500	500	500	500	500	500	500	500	500
Var. Set Up Cost P.A.	20	40	60	90	100	120	140	160	200	400	600	1,000	2,000
Var. Carry Cost P.A.	200	100	66	50	40	33	29	25	20	10	7	4	2
Total Cost of 2,000	20,720	20,610	20,626	20,630	20,640	20,653	20,667	20,685	20,720	20,910	21,107	21,304	22,502
Cost Per Piece S/	10.36	10.32	10.31	10.32	10.32	10.33	10.33	10.34	10.36	10.45	10.55	10.75	11.25

Fig. 3. Combined Cost Curve—using only variable portion of set-up and carrying costs.



No. of Lots Per Annum		1	2	3	EBQ	4	5	6	½ EBQ	7	8	10	20	30	50	100
Q		2,000	1,000	666	633	500	400	333	316	285	250	200	100	67	40	20
Average Inventory £		1,036	516	344	326	258	206	172	163	148	129	104	52	35	22	11
Margin	Per Piece Shilling	0.64	0.68	0.69	0.69	0.68	0.68	0.67	0.67	0.67	0.66	0.64	0.55	0.45	0.25	Nil
	Per Batch £	64	34	23	22	17	14	11	10.6	10	8	6	3	1.5	0.5	Nil
	Per Annum	64	6.8	69	69	68	68	67	67	67	66	64	55	45	25	Nil
Profit % Av. Inventory P.A.		67%	13%	20%	21%	26%	33%	39%	41%	45%	51%	61%	106%	129%	114%	Nil
Cost Per Piece Shillings		10.36	10.32	10.31	10.31	10.32	10.32	10.33	10.33	10.33	10.34	10.36	10.45	10.55	10.75	11.25

Fig. 4. Effect of batch size on average inventory and profit ratio.

2. where now is the justification for the enormous bill this country pays for "obsolescence", due largely to out-of-balance ordering ?

Before we leave this topic of the "economic batch quantity", I would like to make one thing perfectly clear. I am not in any way underestimating the importance of cost reduction in industry.

I do believe that costs can and should be reduced; by improving design, by improving production methods, by more efficient buying, by better management and particularly by increasing output.

I do not believe that costs can be reduced by "fiddling" with the batch quantities for different parts.

4. the case against the theorem that minimum costs give maximum profit

We now come to the *minimum cost/maximum profit* theorem.

(a) *profit and investment*

When we consider profits there are really two different "systems", which have to be taken into account :-

1. profit margin = selling price — cost;
2. investment = k x the cost of one batch.

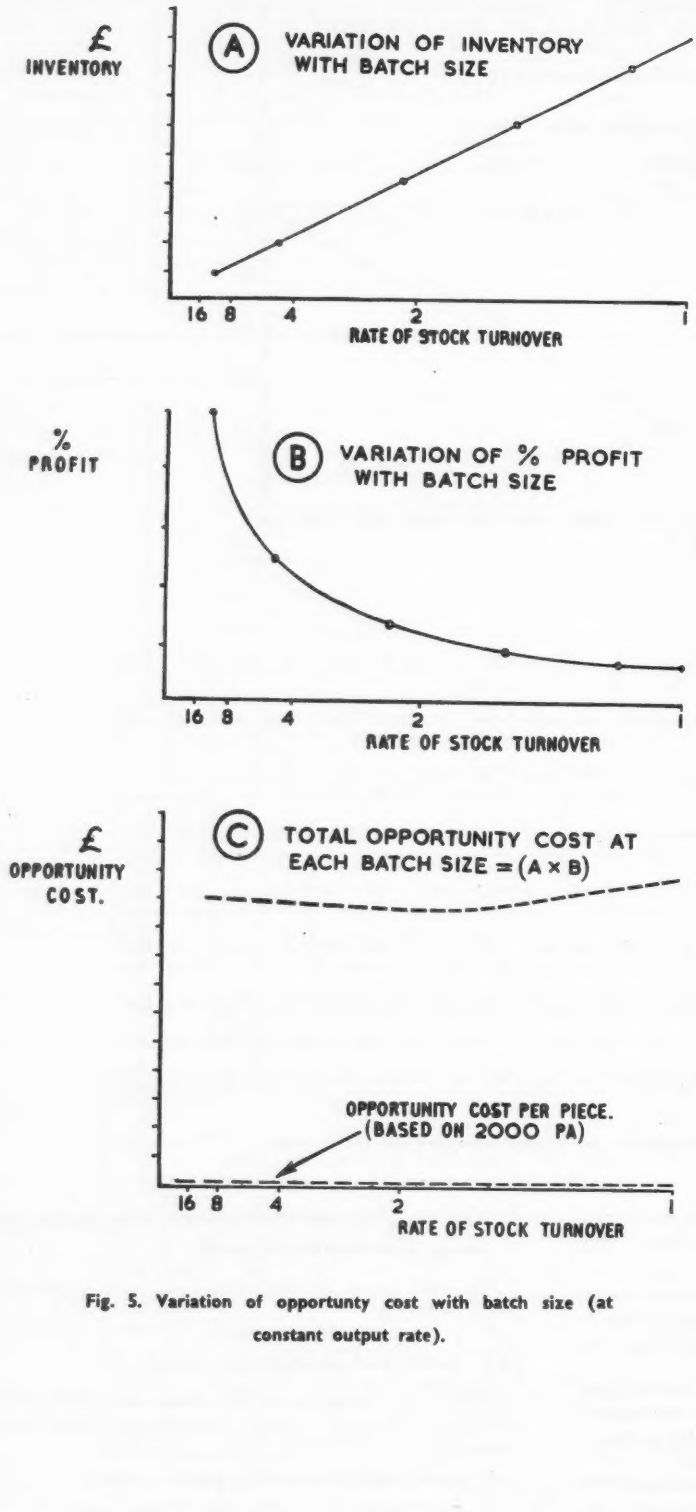


Fig. 5. Variation of opportunty cost with batch size (at constant output rate).

The profit margin per product then, is at a maximum when the cost per product is at a minimum, but a company with a fixed amount of capital, desiring to obtain the maximum " profit ", must look farther and also investigate the investment. The chosen size of investment will largely control the number of times they can take this profit per product in the year, and the amount of benefit they can get from the effects of compound interest.

The investment, as shown in the second formula, is directly proportional to the size of the batch.

(b) *the effect of batch size on ratio of profit*

Profit margin, on the other hand, varies very little with batch size, because profit margin is the difference between fixed selling price and cost per piece. We have already seen that cost per piece varies little over a wide range of batch sizes, so profit margin per piece must behave in a very similar way, getting slightly smaller as cost per piece gets slightly larger.

If now we reconsider our previous example and draw a new illustration (Fig. 4) to show these facts, together with an arbitrary selling price for the part of 11 (eleven) shillings, we find that reducing the batch size from the economic batch quantity to half that size, increases the profit ratio from 21% up to 41%, because the investment has been halved, whilst the profit margin has been only slightly reduced.

This increase in profit ratio is at simple interest and if we take into account the effect of compound interest, the advantage of working in the smaller batch size will be even more marked.

(c) *the effect of batch size on total profit*

At first sight you may feel that I have tricked you, by substituting a profit ratio for a total margin of profit. This is not, however, the case, because the total profit earned will also increase when the liberated second half of our original investment is put to some other profitable use.

If we examine the particular case of our example, we find that the only advantage gained when the economic batch quantity is used (instead of two batches of half the EBQ), by the additional investment of the second half of the inventory, is a small

reduction in cost of 12.66s. for the 633 parts (633 × .02s.). This represents an investment of £163 at a marginal profit of 0.54%.

I am quite sure that most boards of directors could find ways of obtaining a better return than this. I am equally convinced, however, that there are hundreds of millions of pounds invested in industry in "stocks and work in progress", at marginal interest rates of this low order.

(d) *opportunity costs*

In the preceding examples, for simplicity I have used a flat rate of interest applied to the average inventory to cover all carrying costs, including the cost of the capital invested, or in other words the "opportunity cost".

This is the usual method adopted in batch quantity calculations, but I don't believe it is an accurate one, because I don't believe that the "opportunity cost" does vary linearly with changes in batch size.

The "opportunity cost" can be defined as: "The profit we forego, when we tie up capital in production". I am going to postulate here, from my experience in industry, that the profit we usually forego on tying up capital in one job, is the profit we would have got by putting the money back to work in the same business on some work of a similar nature.

I do not believe that there is any general experience to justify the argument that if some of the capital were not tied up in the production of a particular product, then it would be invested in Government stock, or in preference shares, or in some similar way to obtain a flat rate of interest. The effect of having a large investment in fixed capital is to make it difficult to find a more profitable investment outside a company than can be found inside.

The opportunity cost can then be found by multiplying the average inventory under any given conditions by the average rate of profit that will be earned under the same conditions.

We have already seen that the rate of profit or return tends to rise as batch sizes are reduced (and stock turnover rates increased), so the curve for opportunity cost in relation to batch size will not be a straight line, but a curve like that shown in Fig. 5.

If we now consider the return on an investment, such as that required to produce the parts for a given product at the rate of one batch per annum, we find that reducing the batch size progressively — and at the same time increasing the number of batches per annum so as to obtain the same total output — has little effect on the margin of profit earned on the year's production of that product, but has a big effect, as shown diagrammatically in Fig. 6, on the "opportunity profit".

Even though Fig. 6 is only a diagram, and such a smooth transition from one rate of stock turnover to another could not be achieved in practice, it does illustrate the true trend of profit in relation to stock turnover.

If, by reducing batch sizes, we don't tie up all the circulating capital and don't incur the "opportunity cost", we must by very definition gain an "opportunity profit". The total profit earned on this investment will be at a maximum, when the rate of

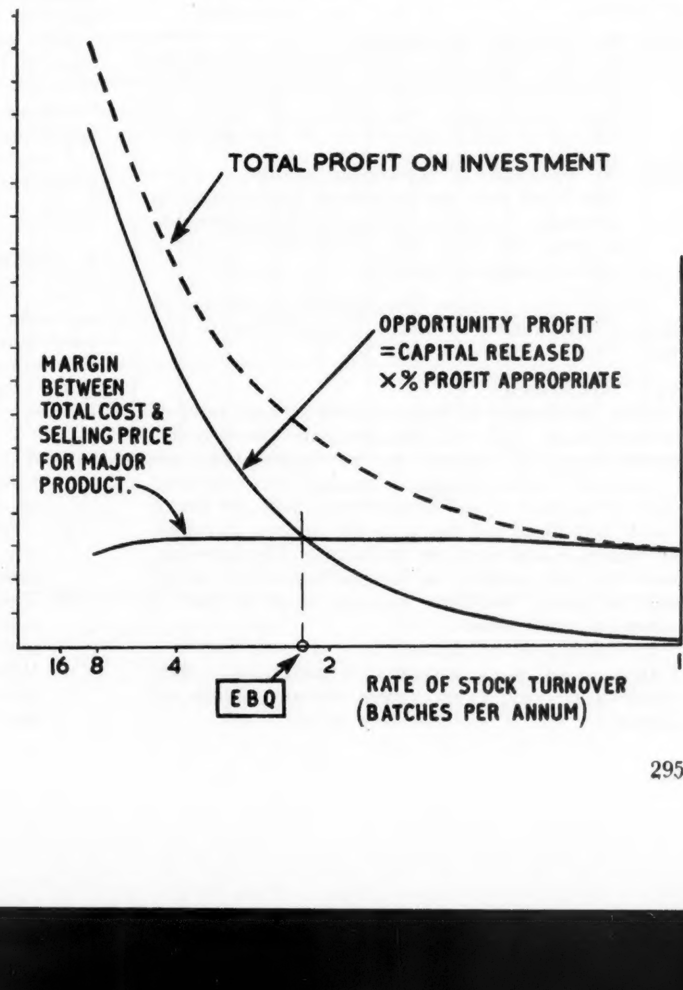


Fig. 6. Total profit on a fixed investment (variation with stock turnover rate).

NOTE—It is assumed that with a stock turnover rate of one batch per annum, all the circulating capital is used for one major product. As the turnover rate is increased progressively, capital is released, which earns additional profit at the appropriate rate for that rate of stock turnover (see Fig. 5).

stock turnover is at a maximum. The batch size for maximum profit is much smaller than the batch size for minimum cost.

(e) *conclusion*

It is not " minimum cost ", but " maximum turnover rate " which gives maximum profit.

There is nothing very revolutionary or new about this idea. Expressed by the slogan " small profits and quick returns ", it will be recognised as the guiding principle of both the jobbing shop and of most of the big line production plants in, for example, the automobile industry. It is only in batch production that — misled by the false principles of the " economic batch quantity" and the "minimum cost/maximum profit" theorems — we have ignored the overriding importance of high stock turnover.

Cost can be sacrificed, within reason, in order to increase the turnover rate, and this will generally increase profits. An additional advantage of increasing the rate of stock turnover is that a given output can be maintained with less circulating capital.

The theorem that minimum cost gives maximum profit is, in its industrial context, wholly false.

5. alternative principles

I hope that by now I have convinced you of the unsoundness of the two main principles which today govern Production Control in batch production industries.

It would not be ethical for me to destroy one set of principles, without at least attempting to substitute alternatives.

I therefore submit for your consideration, two new principles :-

(1) the principle of balance

The most economical form of ordering in batch production for assembled products, is one in which the special materials and parts are ordered in balanced product or assembly sets.

(2) the principle of maximum profit

The batch size for maximum profit tends to approach that size, which gives the largest rate of stock turnover, with which there is still a positive margin of profit.

The adoption of these principles has a number of obvious advantages, of which I would like to cite two :-

(a) *obsolescence*

First, production in balanced sets at high rates of stock-turnover will tend to eliminate obsolescence. Obsolescence is bound to be high with the " economic batch quantity ", because each different part of the product will be made in a different size of batch and there will be no point in time at which all materials and parts are in balance. The introduction of a new product, or the modification of an old one, is bound, therefore, to cause a great deal of expensive obsolescence.

If ordering is in balanced sets of parts, and if a high rate of stock turnover is maintained, then obsolescence just cannot arise to any significant degree.

(b) *control of finance*

My second point is that these two principles give better control of finance. In a factory which accepts the theorem of the economic batch quantity, there may be, say, 10,000 different parts, all made in separately fixed batch sizes. As no board of directors can possibly deal with all the detail involved in selecting 10,000 batch sizes, they normally delegate this duty to someone down " the line ", possibly someone in the Production Control or Production Engineering Department. However, as we saw earlier in this Paper, it is the selection of batch size which controls the investment of circulating capital and any board of directors which delegates this duty is delegating its prime responsibility, which is to see that the company maintains enough circulating capital in liquid form to stay alive.

Most boards of directors imagine that they control finance, but in actual fact the men who really control the investment of the circulating capital in industry today are the comparatively junior officials who fix the batch quantities. The directors probably have a " financial control " system to tell them when things get in a mess and they run round and put things right when they get too bad, but you can hardly call that " control of finance ".

With production in balanced sets of parts, the board of directors can retain full control of financial investment, by approving the size of batch and standard schedule for each product or, alternatively, by specifying the period requirement which may be ordered at any one time and the time in advance of requirement date at which such orders can be released.

Directives such as these are much easier to issue, check and control, when they concern a small number of products or assemblies, than is the case when thousands of different parts have to be considered individually.

I consider this matter of control of finance to be of outstanding importance and, therefore, emphasise it in this context.

6. investment policy

Let us look at this investment problem again and see what it is that we actually do in engineering batch production today, to control the investment of circulating capital.

We can tabulate the usual steps taken, as follows :-

1. The designers design the product choosing the materials and material form to be used, largely on the basis of personal preference.
2. The design is passed to the production planners, who are instructed to plan the methods of production.
3. They are told to plan for " minimum total cost ", so setting-up expense tends to be ignored.
4. When they have finished planning, batch sizes are fixed, their size being controlled largely by the setting-up expense.

5. These batch sizes are then used for production.
6. If the use of these so-called "economic" batch sizes ties up more circulating capital than is available (it generally does), the financial control system eventually shows up the trouble and if extra capital cannot be borrowed, emergency action is taken to correct the position by an arbitrary reduction of batch sizes.

This is surely the most outstanding example of putting the cart before the horse that it would be possible to devise.

In my opinion, the only logical way to tackle this problem is to start in the board room by fixing the rate of stock turnover which it is desirable to maintain. This policy decision can be translated into executive directives by, for example, fixing the batch quantities (in balanced product sets) for each product and approving the delivery schedules to be used for ordering.

Once the batch quantities have been estimated and not until then, the production planners should be told to plan production, using the most economical forms of material and production methods possible, with these fixed batch quantities.

The real problem is not an economic one with technological limitations, but a technological problem with economic limitations.

7. the choice of materials and of production methods

The crux of this problem is how should we choose the material form and production methods for a given product.

All engineers realise that there is a choice in most cases. For example, we can use either sand castings or die castings; bar or drop forgings; capstan lathes or six-spindle automatics. We know there is a choice governed by the volume of production, but the difficulty is to know where to draw the line.

In my opinion the line is very clearly drawn for us by the economic limitations of the business and by the need to maintain an economic rate of stock turnover.

No one will deny that it is desirable by all possible means to increase output — by better sales and by rationalisation and standardisation of design, for example — so that advantage can be taken of the lower costs associated with high output.

It is, however, plainly uneconomic, if in a given case we are "stuck with" a low volume product, to allow the designers and production planners to dictate the use of high volume material forms and production methods, and then to reduce stock turnover, in order to get an apparent reduction in cost per piece.

These apparent savings are more than offset by the losses due to obsolescence and by the loss of profit caused when both total output and the rate of stock turnover are reduced.

8. practical applications

Some of you, by now, may be wondering if all this is some airy-fairy theory which has never been tried out in practice.

I will admit that I know of only two current systems of Production Control in which both the "principle of balance" and the "principle of maximum profit" are observed, but both these systems have been extensively used and are well proven in practice.

(a) *line production*

The first of these systems of Production Control is "line production".

Balanced production in product sets is, of course, the very essence of "line production" and, as far as using high rates of turnover to get maximum profit is concerned, line production goes to the absolute limit by standardising on production in a rapid succession of balanced product sets, with the minimum batch size possible.

Few engineers will quarrel with the idea that line production does give the maximum profit, in the limiting cases where there is sufficient volume to justify its use. I wonder how many, however, have noticed that even in line production we sacrifice direct cost, or in other words accept a higher direct

Assembly Programme										Year: 1957		
	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Product A	30	30	30								30	27
,, B				26	28	28	28	16	28	28		
,, C	12	12					12	7				
,, D			16	14								
,, E									16	16		
,, F					35	35					35	30

Fig. 7. Period Batch Control.

cost than the optimum, in order to get balance and a high rate of stock turnover.

There must be a very few line layouts on machining, for example, where at least one machine or station is not running below optimum speed and feed. In most cases, in fact, there will be only one machine running at optimum speed — probably a tapper — and all the others will be running below optimum, in order to get a balanced even flow.

(b) *period batch control*

The second system of Production Control, which follows both the "principle of balance" and the "principle of maximum profit", is "period batch control".

This system was devised by Mr. R. J. Gigli in about 1926 and has been widely applied in a great many batch production industries by the firm of consultants of which he is a director.

In "period batch control", the programme is divided into periods — the 12 calendar months might be used, for example — as in Fig. 7, and the total requirement for each period is then ordered in turn, to a standard manufacturing schedule.

For example, if the standard manufacturing schedule for the provisioning of parts for assembly is two months, then all the component orders for the July assembly period will be released on 1st May for completion by 1st July.

As the production programme — or building programme if you prefer that term — shows numbers of products, then ordering will be in balanced product sets.

By dividing the programme year into a large number of periods and by tightening the manufacturing schedule to the optimum, it is possible to get very high rates of stock turnover.

I should mention here that there is a possibility that the name "period batch control" may be a "debased currency". I know myself of firms who use a system called "period batch control", which has been modified so that parts are ordered in so-called "economic batch quantity" lots. Such a modification immediately destroys all the main advantages of the original system and leaves things just as bad as they would be with a normally inefficient "stock control" or "component batch scheduling" system.

(c) *conclusion*

The policy of ordering in balanced product sets with a high rate of stock turnover is not new to engineering. It has already been tried and proved for both line production and batch production.

9. difficulties in high stock turnover in batch production

It is now time to admit that the path of high stock turnover in batch production industries is not quite as simple as I have made it sound. There are difficulties, which can be classified as :-

1. technological difficulties;
2. difficulties of control.

(a) *technological difficulties*

The technological difficulties concern themselves mainly with the process of setting-up. Although any small addition to set-up time caused by the use of small batches does not have a great effect on preparation expense, or on cost per piece, over a wide range of possible batch sizes, and although any increase is amply repaid by an increase in profits, there is one way in which any increase — however small — in total setting-up time will be deleterious. It will reduce capacity.

I confess that this doesn't worry me at all. I know that in most of the engineering industry, "setting-up" is a subject in which no one is very interested and in which there is enormous scope for improvement. Provided that the Production Engineers show some reduction each year in direct costs, in most engineering companies no one worries much if their new tools take twice as long to set-up.

The general solution to the setting problem in batch production today is to say: "Set-up times are long, therefore batch sizes must be big". This only dodges the real problem which is: "Set-up times are long, how can they be reduced ?".

If the problem is recognised, then setting-up times can very easily be reduced. For example, in machining, any of the following policies will give a bigger increase in capacity than could ever be obtained by increasing batch sizes :-

1. work study of the setting operators;
2. setting teams instead of individual setters;
3. pre-setting of tools in quick change toolholders;
4. the scheduling of operations so that similar jobs are loaded in sequence on the same machine;
5. the use of a classification system to reduce diversity ;
6. the design of special tooling so that it will handle a number of similar parts without resetting;
7. production planning for the minimum number of different operations;
8. the use of co-ordinate setting techniques;
9. programme machining (change cards to change set-up);
10. the use of plant designed for quick set-up change — copy turning lathes, turret punches, etc.;
11. where output is sufficient, the use of special purpose machines and automation.

Setting-up time is an important factor in industry, because of its effect on capacity, but reducing the rate of stock turnover is probably the most inefficient method that could possibly be chosen to reduce it.

(b) *difficulties of control*

The second difficulty — that of control — is a far more serious one.

With most common systems of Production Control, such as "component batch scheduling" and "stock control", the halving of all batch sizes is accompanied by the doubling of all paperwork. It follows then

that any ambitious programme of increased stock turnover can easily get into a chaotic state, where the factory is producing more waste paper than products.

Even "period batch control" suffers to some extent from this difficulty and I propose now to describe a system, which I have called "standard batch control", which will, I believe, give full control at high rates of stock turnover, with less paper.

10. standard batch control

Following normal processes of simplification, I have tried to establish a larger standard unit of control to replace the "batch of parts", which at present is the unit most commonly used.

I have selected for this purpose the standard batch of products, or of assemblies. In a factory where there are 10,000 different current assembly parts in production and an average number per product of 200, this will reduce the number of standard units to be controlled from 10,000 to 50.

The size of the standard batch for each product will be fixed so that 8, 10, 12, or any desired number of batches has to be released at intervals during the year to obtain the required output; the actual size, or number of products per standard batch, being fixed to give the rate of capital turnover required.

I have already described the system of standard batch control at length in a book of that name * and here I will content myself with a brief description of its main features. These are :-

1. The parts for each product are always ordered in standard batches, supplying sufficient parts to make a standard number of products, plus allowances for scrap and spares.
2. All ordering is done to a standard schedule for each product with a set period allowed for each department concerned (including buying), in which to do its operations on the batch.
3. The orders on each department are issued in the form of lists.
4. The responsibility for finishing the lists by due-date is delegated to the shop foremen, or managers, and to the buyers.
5. A modified form of storekeeping is used, in which the assembly parts from each batch by-pass the stores and flow directly through the departments to assembly, and only the surplus — consisting mainly of spares and allowances for assembly scrap — is removed and held in controlled stores.

Figs. 8 and 9 illustrate these features.

(a) *the production programme and the standard schedules*

Fig. 8 shows, at the top, an assembly programme laid out for standard batch control; and, at the bottom, the standard schedule for one of the products.

If the programme and the standard schedule are both drawn to the same scale, it will be a simple

* "Standard Batch Control" by J. L. Burbidge. *Macdonald & Evans, London.*

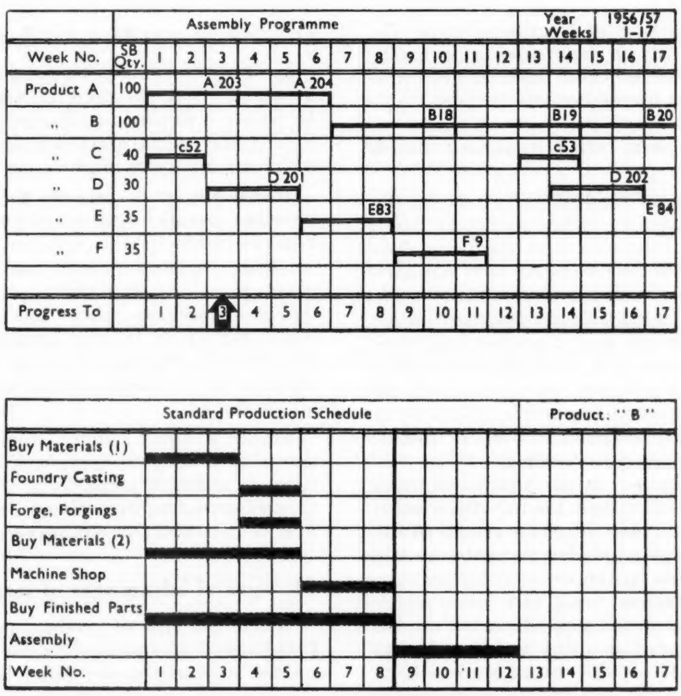


Fig. 8. Standard Batch Control.
Programme and Standard Production Schedule.

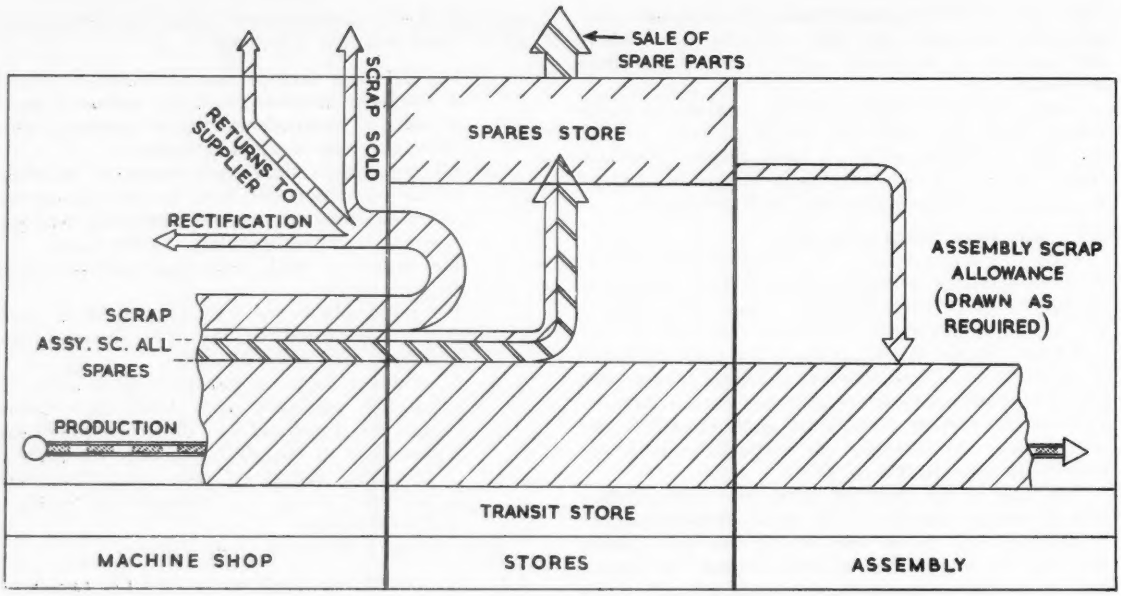


Fig. 9. Flow of standard batch through stores.

matter to find the starting and finishing dates for work in each department on each succeeding batch, merely by holding the schedule against the programme, with the start-assembly dates in line.

(b) *the flow of parts with standard batch control*

Fig. 9 shows the flow of finished parts between the machine shop and assembly, when standard batch control is used. It will be seen that the main flow of parts for assembly is accumulated into standard batches, in what I have called a transit store, while the surplus, consisting of spares and of allowances for assembly scrap, is removed and is placed in a conventional controlled store. The controlled store will have a fixed bin location for each item stocked and a stock card for every part with maximum and minimum values, so that any tendency to over- or under-provisioning of spares can be corrected.

The receiving storekeeper in the stores will have copies of the machine shop and buying department order lists and will maintain a complete record of the stocks ready in the transit store for assembly, merely by crossing off each item on the list as it arrives.

It is only in the comparatively rare case, where there is so much scrap on a batch of parts that the scrap allowance and spares quantity is rejected, that the quantity of any part in the transit store will be sub-standard. In this case it will probably be possible to make up the assembly quantity from the spares stocks, pending completion of a replacement batch.

(c) *where standard batch control can be used*

I do not submit standard batch control as a universal system to cover all engineering production. Its utility is limited, in the first place, to the production of the special parts for assembled products, for which the majority of parts are made in batches.

Inside any given factory, then, there will have to be other parallel systems of control, to cover other types of production, such as the "jobbing production" of spare parts for old products; the "contract production" of materials and parts to customer's delivery schedules; the "line production" of any items, for which there is sufficient volume to justify this method of production and the "scheduled item purchasing" of common materials and parts used on all products.

Standard batch control, again, is ideal when the design of product is fairly well established. For those types of assembly production, where the design tends to vary considerably between one sales order and the next, I personally would prefer period batch control.

11. special advantages of standard batch control

Where the type of production is suitable, however, I believe that standard batch control has certain special advantages over other systems of Production Control for the batch production of parts for assembled products and I would like now briefly to mention two of them :

(a) *reduction of paperwork*

First, I would like to substantiate my claim that standard batch control requires considerably less paperwork than do conventional systems of Production Control.

Let us imagine a factory making a number of products by batch production methods and suppose that there are five main departments engaged :-

1. foundry;
2. steel store (equipped with saws for cutting-off);
3. machine shop;
4. buying;
5. assembly.

To order the provisioning of a batch of products by conventional methods, if there were, say, 400 parts involved, would require :-

(a) 400 material "shop orders" or "purchase requisitions" ; and

(b) 200 (say) machining "shop orders".

Total : 600 pieces of paper.

To order the same production by standard batch control, only five order lists would be needed :-

1. foundry; 2. buying (materials); 3. bar stores (cut blanks);	All for delivery by (say) 1st July
4. machining; 5. buying (finished parts).	Both for delivery by (say) 1st August.

This reduces 600 documents to 5 — a fairly substantial reduction in ordering alone.

But let us now consider progressing. In a typical present-day system, copies of all the 600 orders and purchase requisitions would be sent to the Progress Office, where they would be filed in special cabinets and marked up daily, so that a list of overdue orders could be prepared.

With standard batch ordering, the provision of these 600 copies can be avoided. The actual orders in the shops are themselves "orders overdue lists" which can very simply be kept up-to-date by crossing off each part on the list as it is completed.

So far we have saved 1,195 pieces of paper on this single batch, but there are other less spectacular savings. For example, by giving copies of the "machining" and "buying, finished parts" lists, to the receiving storekeeper, he can — again simply by crossing the items off as they arrive — maintain a record of assembly stocks held for the batch, and at the same time a shortage list.

All the tiresome requisitions and assembly issue sheets needed to book assembly stocks out of the stores are eliminated.

It is interesting to note that when ordering is in balanced product sets, the "orders overdue list" and the "stock shortage list" are identical. There is no need to have two systems of progressing ("order progressing" and "shortage chasing") as is generally the case with a conventional Production Control system.

That then is the first advantage I would claim for standard batch control : it reduces paperwork to a minimum and by so doing simplifies and improves control.

(b) *internal forecasting*

A second special advantage I claim for standard batch control concerns that greatly neglected subject, internal forecasting.

I think it will be obvious that, if in a factory we adopt a given sales programme and a given building programme, and if we then produce the parts in batches of standard size under standard conditions — I use the term "standard" here in the sense used in "standard costing" — then we have fulfilled all the major conditions necessary to predict the future course of a large number of related factors.

The weekly schedule for deliveries of all sizes of steel bar, for example; the loads on each work centre at intervals throughout the programme period; the stocks in the stores or — most important — the forecast values for "creditors", "debtors" and the cash position at the beginning of each month; all of these are pre-ordained once we adopt a given combination of programmes and standard conditions and schedules. It should be possible to make accurate predictions of their values.

(c) *internal forecasting with production control today*

With ordinary Production Control systems, however, the knowledge that the information is pre-ordained is of little practical use, as it is almost impossible to forecast its value with any accuracy.

The fact that with most Production Control systems each part has to be treated separately and that they may arrive in the shop in an almost infinite variety of combinations, means that the problem is extremely complicated.

(d) *internal forecasting with standard batch control*

With standard batch control, the standard batches of product sets will have standard properties. Each of the comparatively small number of batches concerned will take up a standard amount of capacity on a number of work centres; it will build up a standard quantity of stocks during its scheduled life and it will tie up a known amount of capital at known times during its progress through the works.

Once these standard properties have been calculated, it will be a relatively simple matter to chart the information and to arrange the small number of charts concerned, on a time grid, so that they represent any given programme. It will then be a simple job to add up the figures arising during each week or period, to get a table of totals (Fig. 10).

This process lends itself to mechanisation and I fully expect to see the day when a managing director can be justifiably annoyed if he has to wait more than half-an-hour after completely recasting the

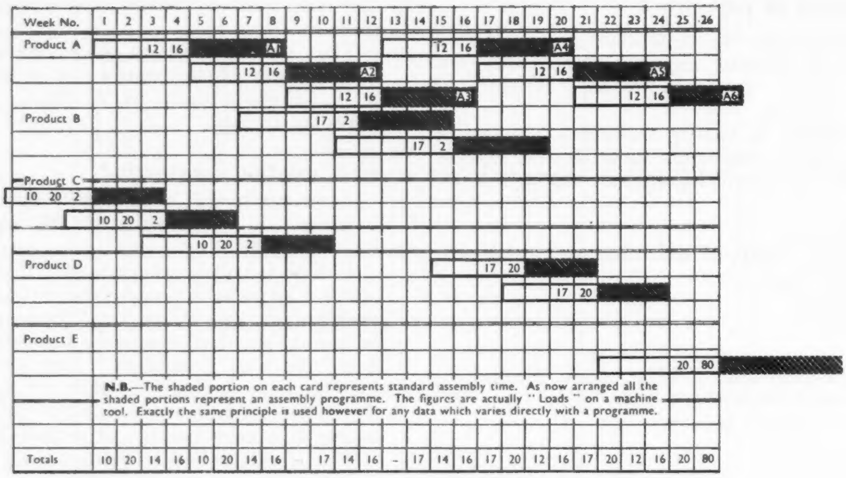


Fig. 10. Using Standard Cards for Forecasting.

production programme, for a detailed liquid capital forecast over the next 12 months.

(e) *forecasting and financial control*

Probably the main reason why accurate and quick internal forecasting is of vital interest to industry is that without it, it is impossible to have real control of finance.

Any " control " consists essentially of three parts :-

1. make a plan or programme;
2. measure deviations from the plan;
3. " feed-back " instructions to the organisation (or mechanism) to correct the deviations.

The trouble with most financial control systems today is not that we fail to follow this procedure, but that instead of one plan there are usually two.

First we have a production programme and various ordering standards, which are fixed by the technical staff. These pre-ordain certain financial results. As, however, we cannot with our present production control systems calculate what these results will be, we then get the accounting staff to prepare a second programme or budget.

Inevitably the two programmes are different and, as each control tries to force finances into its own mould, there is bound to be stress and inefficiency.

12. general conclusions

I would like very briefly to review the conclusions I have reached on this subject, as follows :-

1. if output is constant, varying component batch sizes has an insignificant effect on cost per piece;
2. substantial savings are possible in both costs and capacity, if obsolescence is eliminated by ordering the materials and parts for assembled products in balanced product sets, at high rates of stock turnover;
3. it is not minimum cost, but maximum turnover rate, which gives maximum profit;
4. the capital required to maintain a given output can be greatly reduced by increasing the rate of stock turnover.

When those of us in industry are blamed for the fact that Britain is losing the productivity race and is rapidly sinking into the position of a tenth-rate industrial nation, a favourite excuse is shortage of capital.

I don't believe that there is any real shortage of capital in British industry; we just use what we have very inefficiently.

The total of " stocks and work in progress " for the manufacturing industries in Britain is about £4,000,000,000; if we really tackle this problem of stock turnover, I believe that it would be quite possible to release £1,000,000,000 for reinvestment; to save £100,000,000 a year from our present losses due to obsolescence; to gain the same value in increased capacity and, by increasing rates of profit, to make a considerable increase in our annual rate of growth.

I do feel most strongly that, to survive industrially, British industry must make an entirely new approach to Production Control, and should concentrate its main effort on getting production into balance and on increasing its rate of stock turnover.

Output Pattern in Repetitive Tasks

with special reference to Compensating Relaxation Allowances

by N. A. DUDLEY, Ph.D.(Birmingham), B.Sc.(London), M.I.Prod.E.

PART III

ANALYSIS OF RESULTS

comparison of rates of output

As one of the checks made to ensure that the production studies subjected to detailed analysis did not represent abnormal performances on the part of the workers concerned while under observation, output figures were compared over several successive days including the day of the study (e.g. see Fig. 3). These figures were also compared with records made available in the firms concerned, extending over the previous 12 months.

Overall daily output for each operation (except No. 18), and the average daily output from past records, were expressed as percentages of that for the day of the production study:

overall daily output = units of output produced per working day.

Because of the considerable variations from day to day in the number of hours worked by operators on operation No. 18 the percentages, in this case, were based on average hourly output rates:

$$\text{overall hourly output} = \frac{\text{units of output produced per working day}}{\text{number of hours per working day}}$$

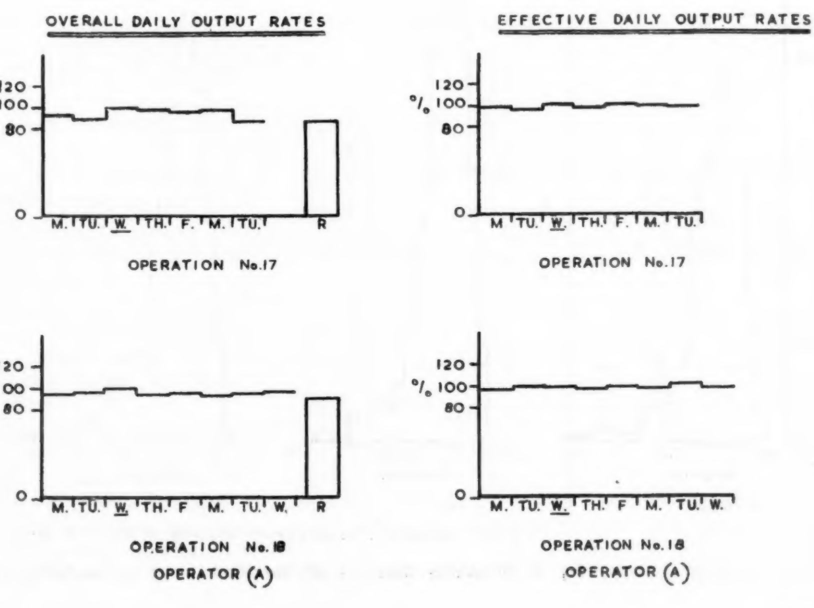


Fig. 3. Output rates expressed as percentages of output for day of production study (underlined). "R" indicates average daily output from past records.

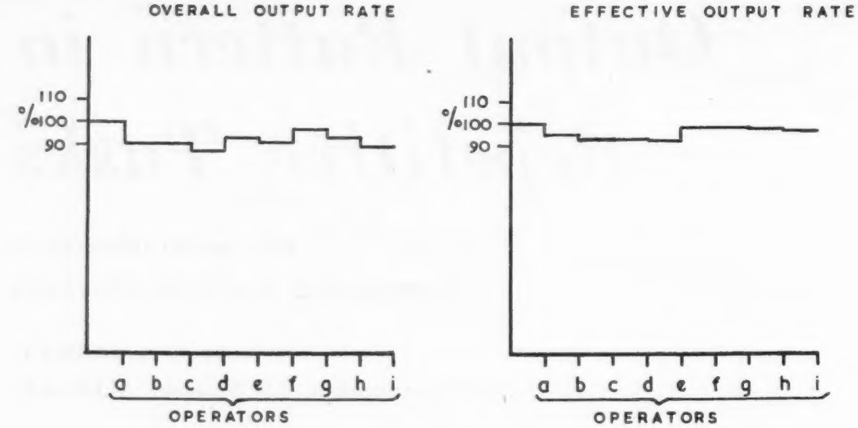


Fig. 4. Overall and effective output rates of nine operators on operation No. 18 on the same day (expressed as percentages of A's output).

From automatically recorded productive time charts and production records, the "effective output rate" was calculated. This effective output rate was also expressed as a percentage of that for the day of the production study:

effective output rate =

$$\frac{\text{units of output}}{\text{time actually spent productively}}$$

From a combined memomotion and production study, overall and effective output rates were also calculated for nine operators on the same day on operation No. 18. In Fig. 4 these are expressed as percentages of operator A's output.

These several comparisons of the average daily output, taken over the previous 6 to 12 months, with the overall daily output achieved during the day of the production study and also during the week in which the study was made, proved that no disturbance of the normal working performance took place due to the presence of the production study observer.

Incidentally, it will be observed that, as compared with the effective output rate which is a more exact measure of working performance, the overall output rates tend to exaggerate the differences in performance not only between operators, but also in

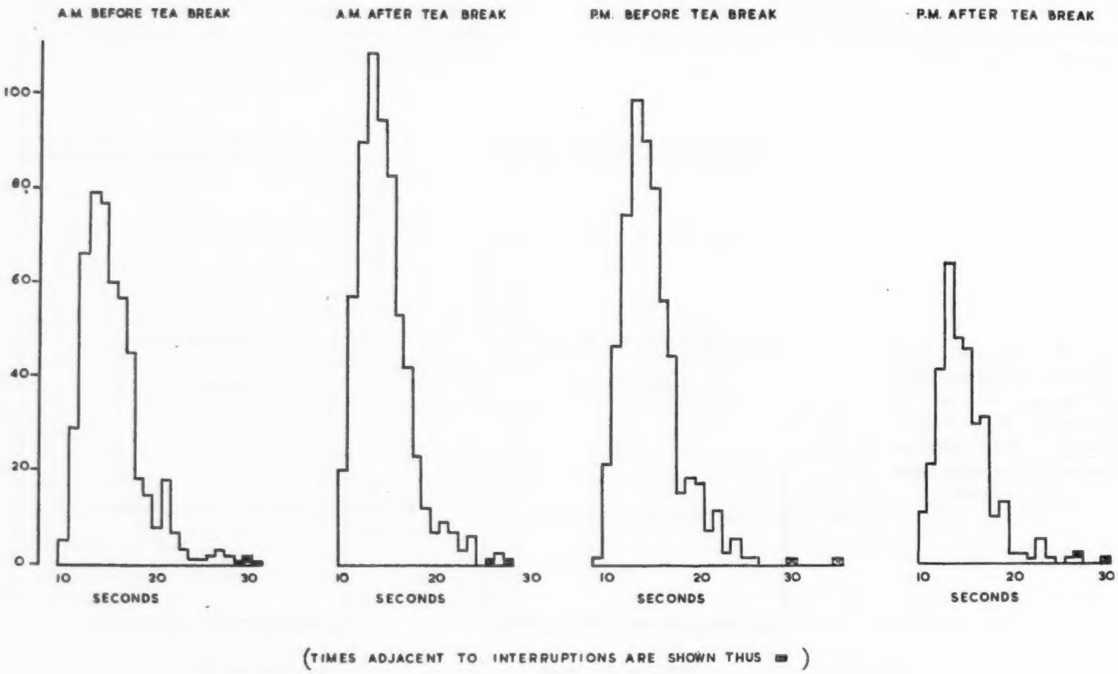


Fig. 5. Frequency diagrams of operation times — operation No. 11.

the performance of the same operator on different days.

These comparisons have also shown clearly that overall measures tend to give a misleading impression of variability in performance, which detailed production studies do not support.

frequency diagrams of operation times

While external comparisons of overall daily performance provide evidence regarding possible abnormalities arising during production studies from the presence of the observer, it is possible to use the detailed operation cycle and element times obtained during the production study, to provide an internal check on two other important factors.

These are :-

(a) to determine whether the operator studied is skilled and accustomed to the task being studied; and

(b) to determine whether the level of skilled performance is maintained at different periods during the working day.

Previous studies 66 by the author have shown that it is characteristic, in the case of a fully skilled operator, for the work element times to have a skew distribution. Frequency diagrams of the operation and cycle times of the operators studied, displayed this skewness, characteristic of the skilled operator (see, e.g. Fig. 5), and it was, therefore, concluded from this evidence that the operators studied were normally skilled and accustomed to the tasks concerned.

Turning now to the important question of the influence of the time of day upon the maintenance of performance level, it was found, in the case of operation No. 9 (see Fig. 6), by an analysis of variance, that while there was a significant difference (0.1% level) between the mean cycle times of the two operators A and B, there was no significant difference in the mean cycle times for periods one and two of the morning and afternoon for each individual operator.

Thus, it was determined for operation No. 9 that :-

1. the mean working pace of each operator remained constant throughout the day, although
2. the mean time taken to perform the operation by operator A differed from the mean time taken by operator B by 6.6%.

Differences in working pace between the operators and, in part, different methods of working employed by these operators, both of whom were equally experienced and working under identical conditions, could account for this difference.

In the case of operation No. 18, comprising four similar elements, no significant difference could be found between the frequency diagrams for the morning and afternoon periods in any of the operation elements (i), (ii), (iii) and (iv) for either operator. The mean times of these elements for operator A were 7, 32, 57 and 125 seconds respectively.

The morning and afternoon frequencies were then combined for the purpose of determining the differences between the operators.

A significant difference was found between the combined frequency diagrams of operators A and B on all elements. In the case of elements (i) and (iv) this difference was only slight (5% level), but very highly significant in the case of elements (ii) and (iii).

Comparison of the frequency diagrams after equating the means (except for element (i) where the means were already the same) revealed that the differences in the case of elements (ii) and (iii) were still significant.

This indicated that for elements (ii) and (iii) the frequency diagrams for operators A and B are different in character, the differences not being caused merely by a difference in the average time taken to perform the element.

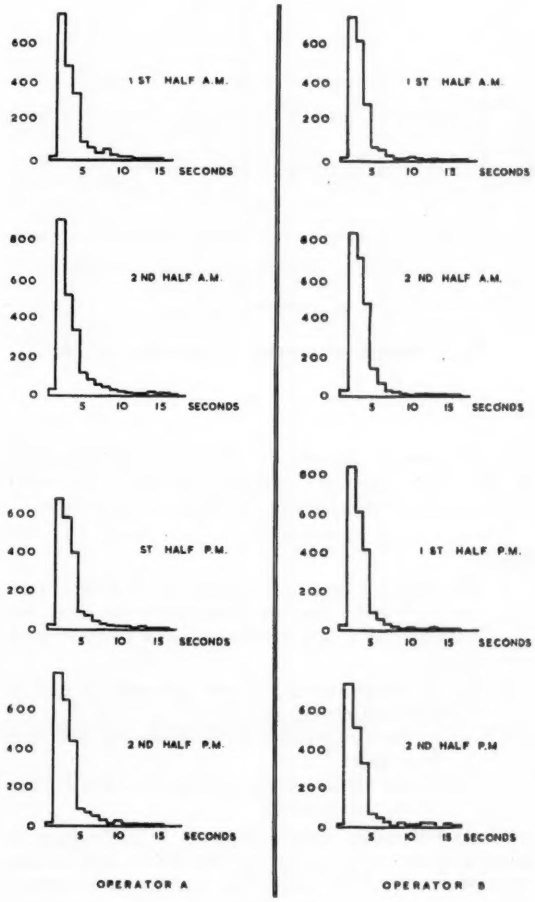


Fig. 6. Frequency diagrams of cycle times — operation No. 9.

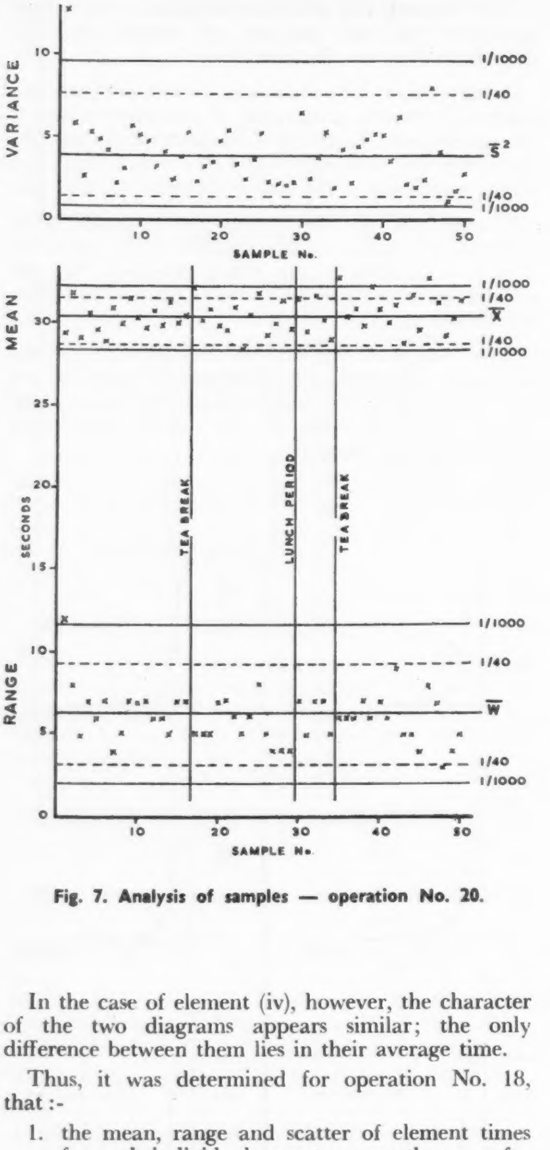


Fig. 7. Analysis of samples — operation No. 20.

In the case of element (iv), however, the character of the two diagrams appears similar; the only difference between them lies in their average time.

Thus, it was determined for operation No. 18, that :-

1. the mean, range and scatter of element times for each individual operator were the same for both morning and afternoon work periods; and that
2. the performance of the two operators A and B differed as follows :
   (a) in the mean times of elements (ii), (iii) and (iv); and
   (b) in the shape of the frequency distribution of all the elements.

These differences were due partly to differences in working pace, as is shown by the differences in the average times for the operators, but, to some extent, also to differences in the experience of the operators, one of whom had two years' and the other over 15 years' experience on this type of work.

In general, therefore, it can be stated that — contrary to generally held theories — over the range of operations studied, there is evidence that skilled operators maintain a highly consistent level and pattern of performance during the entire shift.

analysis of samples

To investigate further whether and to what extent means, ranges and variances of successive samples of operation cycle and element times changed throughout the shift, these values were calculated and plotted graphically for operations Nos. 4 - 8, 10 - 13 and 15 - 20. Since there were no natural groups (except in the case of operation No. 15) the samples represent times arbitrarily divided into groups of 10.

The graphs (see, e.g. Fig. 7) reveal that operation and cycle element times are constant, within close limits, throughout the morning and afternoon shifts, and that there is a complete absence of any statistically significant trend.

This reinforces the findings of the previous section by a much more detailed and stringent analysis, carried out on times from cycle to cycle.

The occurrence of a number of points outside the control limits does not invalidate this observation for the following reasons :-

1. Such points, when they do appear, do not occur at any one part of the work period, but are distributed throughout the period of the study.
2. These points are attributable, in part, to :
   (a) the extreme skewness of the frequency distribution of operation cycle and element times; and in part to
   (b) the effect of interruptions of the work pattern due to ancillary work and operational and personal delays (see Fig. 5).

Examination of the original production studies suggests that, in some cases, interruptions have resulted in changes in the work content of operation elements adjacent to the periods of interruption, giving rise to abnormalities in the times of these elements, and yet not of sufficient magnitude to be classed as " foreign elements " and hence excluded.

regression analysis

Any tendency for operation or element times to change from cycle to cycle can be measured with still more precision by the use of regression analysis, particularly when there are comparatively few operation cycles performed during the work period. Operation cycle and element times for operations Nos. 1, 2, 3 and 14 were, therefore, subjected to regression analysis, for this reason. Operation No. 5 was subjected to regression analysis as well as to an analysis of samples.

Operation No. 1 consists of 16 elements, and 12 complete cycles of the operation were performed both in the morning and in the afternoon shifts. Calculations were made for each element individually, both

for the morning and afternoon periods, and for all elements pooled (morning and afternoon). In each case the regression of element times on cycle numbers is not significant.

In the case of *operations Nos.* 2 *and* 3, two operators were studied on each operation because of the frequent interruptions of the work cycle due to the necessity of attending to the machine.

Analysis, here, was undertaken to determine the regression of the cycle time (y_1) on the cycle number (x), and the regression of the cycle time on the number of interruptions of the cycle (y_2) ignoring the cycle number.

The findings and conclusions are as follows :-

Operation No. 2 (*operator A*)

The regression of y_1 on x is significant at 5% level.

Regression equation : $y_1 = -5.35x + 1316.05$.

The effect of the regression is to account for about a quarter of the variance of y_1.

The regression of y_1 on y_2 is not significant.

Thus, the number of interruptions appears to have no effect upon the operation time, and there is some evidence that the operation time *decreases* in successive cycles.

Operation No. 2 (*operator B*)

The regression of y_1 on x (ignoring y_2) is not significant.

The regression of y_1 on y_2 (ignoring x) is not significant.

Regression equation of y_1 on y_2 and x :

$$y_1 = 854.15 + 25.36y_2 + 5.86$$

Thus, considering each independent variable separately, there is apparently no regression. Considering both variables together, it appears that the operation time certainly depends on the number of interruptions (significant at 0.1% at least) and *may increase* with cycle number (just below 5% level of significance). The two regressions together account for about two-thirds of the variance of operation times.

Operation No. 3 (*operator A*)

The regression of y_1 on x (ignoring y_2) is not significant.

The regression of y_1 on y_2 (ignoring x) is highly significant.

The operation time depends strongly on the number of interruptions, but there is no evidence of any dependence on cycle number. The regression accounts for about 93% of the variance of operation times.

Operation No. 3 (*operator B*)

The regression of y_1 on x (ignoring y_2) is significant at the 5% level.

Regression equation : $y_1 = -8.96x + 1275.58$.

The regression of y_1 on y_2 (ignoring x) is significant at the 5% level.

Regression equation : $y_1 = -32.90y_2 + 1368.98$.

Regression equation of y_1 on y_2 and x :

$$y_1 = 1096.80 + 34.05y_2 - 9.13x.$$

In this case there is no regression between the number of interruptions and the cycle time. The separate regressions are both significant and little altered when both are included in the analysis (the difference is, in fact, mainly due to rounding off errors). Here again the operation time *decreases* with cycle number. The regressions account for about half the variance of operation times.

Operation No. 5 comprises two elements, the second of which is repeated in each operation cycle. The regression of the first element times (y) on the cycle number (x) is not significant. The regression of the second element times (z) on the cycle number was significant at the 5% level.

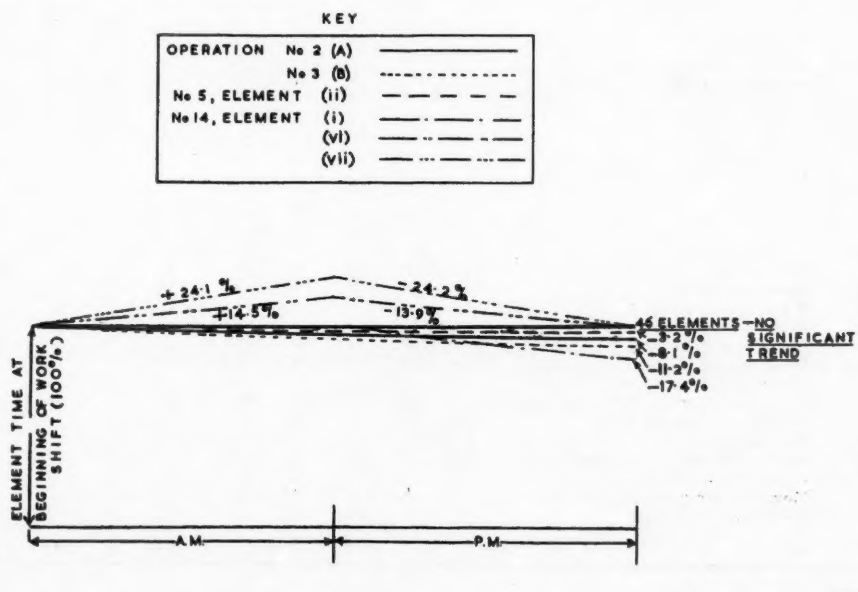


Fig. 8.
Diagram showing trends in operation element times over the work period.

Regression equation : $z = 412.092 - 0.426x$.

A test for curvature of this regression showed that this was not significant.

Operation No. 14 consists of eight elements, 35 cycles being completed during the morning period of the study, 41 in the afternoon. The regression of element times (morning and afternoon times calculated separately) on cycle number was :

1. *not significant in* 11 *cases;*
2. *barely significant in three cases at the* 5% *level* (Element (i) p.m. negative, (vi) a.m., and (vii) a.m., positive);
3. *significant in one instance* (Element (vi) p.m., negative) *at* 1% *level* and *in one* (Element (vii) p.m. negative) *at* 0.1% *level.*

Of the eight elements of this operation, elements (vi) and (viii) together account for about 10% of the total operation cycle time.

To summarise the results noted above, it is shown that, in general, element times remain constant, within close limits, during the working shifts, and that an occasional element time may decrease as well as increase over the working shift. This is shown diagrammatically in Fig. 8.

analysis of motion pattern (micromotion study)

In order to determine whether there was any trend, during the work shift, in the relative duration of operator motion times within the operation elements, samples of operation elements were filmed and analysed.

These samples were taken, at four different periods of the work shift from several operations.

From each of the four samples of each operation were selected operation elements of common duration for analysis of the motion pattern.

A comparative study of this analysis (see Fig. 9) reveals :-

1. that the motion pattern remains constant within elements of common duration (i.e., within elements performed at the same working pace), irrespective of the period of the work shift; and
2. that differences in the relative duration of operator motions within elements of different time length are attributable to voluntary changes in working pace [67].

analysis of productive and non-productive time

Since the previous analyses showed that operation element and cycle times (i.e. directly productive time) remained constant, within close limits, and that there was an absence of any statistically significant trend throughout the working period, a further analysis was made of the magnitude and distribution of time lost by reason of personal and operational delays, and of time spent on ancillary work.

Fig. 9. Analysis of motion times (extract).

Op. No.	Description of Operation Element and Operator Motions	Motion Times expressed in Terms of Number of Frames of Film											
		Example (1) Samples				Example (2) Samples				Example (3) Samples			
		a.m.		p.m.		a.m.		p.m.		a.m.		p.m.	
		1	2	3	4	1	2	3	4	1	2	3	4
13.	*Bend Ends of Lamp Body (L.H.)*												
	Grasp Component	2	2	3	2	2	2	2	2	2	2	4	3
	Move to press	5	4	4	4	4	5	5	5	5	6	6	4
	Position in tool	4	4	5	5	6	5	5	5	7	6	6	6
	Hold and regrasp	5	6	6	5	9	10	10	9	15	12	16	14
	Turn pressing over	5	4	5	3	4	4	4	5	9	7	6	8
	Position in tool	2	3	2	2	2	3	3	2	4	4	4	3
	Release and regrasp	5	4	6	4	7	7	8	9	12	12	11	15
	Move Component to Conveyor	4	3	3	4	6	7	5	5	8	6	6	7
	Release Component	2	2	1	2	2	2	2	2	2	2	2	2
	Total	34	32	35	31	42	45	44	44	64	57	61	62
11.	*Assemble switches (R.H.)*												
	Pick up component A	12	10	9	10	11	12	9	14	14	17	15	12
	Move to fixture	5	6	6	5	6	6	5	5	8	6	9	7
	Position and release A	9	12	9	13	22	20	25	18	30	28	32	32
	Receive B from L.H. and move to fix ...	6	5	5	5	6	5	4	5	7	5	8	7
	Position and release B	15	14	11	14	24	19	26	20	34	29	30	34
	Move to L.H.	4	4	3	3	5	4	4	3	4	6	5	3
	Grasp C.	7	8	10	10	12	12	11	14	19	23	22	20
	Move to fixture (including pre-position) ...	14	16	16	15	18	17	16	17	25	29	21	18
	Position and release C	15	17	18	17	26	25	22	20	45	40	53	44
	Regrasp pliers	6	4	4	5	5	7	7	6	11	12	10	8
	Move to fixture and preposition	7	4	4	4	7	8	4	8	11	10	9	12
	Bend 1st pair of tags	37	35	30	29	50	52	49	57	62	58	62	64
	Move and pre-position	5	5	4	5	5	6	3	5	6	7	6	5
	Bend 2nd pair of tags	30	29	36	30	52	56	57	50	68	75	60	78
		172	169	165	165	249	249	242	242	344	345	342	344

Operation No.	Period of Day	% PRODUCTIVE TIME			% NON-PRODUCTIVE TIME			
		Direct Work	Ancillary Work	Total	Operational Delays	Personal Delays		
						Tea Break	Relaxation and Personal Needs	Total
1	a.m.	84.61	7.50	92.11	1.78	6.11	—	6.11
	p.m.	83.64	5.94	89.58	1.81	6.48	2.13	8.61
	Total	84.13	6.72	90.85	1.79	6.30	1.06	7.36
2(a)	a.m.	87.31	5.07	92.38	.68	5.27	1.67	6.94
	p.m.	80.11	11.35	91.46	1.24	5.50	1.80	7.30
	Total	83.82	8.12	91.94	.95	5.38	1.73	7.11
2(b)	a.m.	80.00	12.81	92.81	.40	4.50	2.28	6.78
	p.m.	75.30	15.56	90.86	1.57	5.19	2.37	7.56
	Total	77.72	14.15	91.87	.97	4.83	2.33	7.16
3(a)	a.m.	80.84	12.59	93.43	1.79	4.44	.33	4.77
	p.m.	70.76	13.47	84.24	10.08	5.34	.34	5.68
	Total	75.94	13.02	88.96	5.82	4.88	.34	5.22
3(b)	a.m.	68.85	18.69	87.54	4.94	5.85	1.68	7.53
	p.m.	61.46	22.60	84.07	8.19	6.00	1.75	7.75
	Total	65.26	20.59	85.85	6.52	5.92	1.71	7.63
4	a.m.	88.22	2.74	90.96	2.69	3.86	2.49	6.35
	p.m.	82.79	4.52	87.31	3.91	5.74	3.04	8.78
	Total	85.82	3.52	89.34	3.23	4.69	2.73	7.42
5	a.m.	85.50	6.15	91.65	4.06	4.29	—	4.29
	p.m.	87.90	1.38	89.28	5.24	4.94	.54	5.48
	Total	86.56	4.04	90.60	4.58	4.58	.24	4.82
6	a.m.	90.17	2.44	92.61	2.05	3.86	1.49	5.35
	p.m.	84.20	3.37	87.57	4.64	6.05	1.75	7.80
	Total	87.50	2.85	90.37	3.20	4.84	1.60	6.44
7	a.m.	80.37	8.95	89.32	4.42	5.06	1.20	6.26
	p.m.	90.15	1.39	91.54	1.79	5.04	1.63	6.67
	Total	84.97	5.39	90.36	3.18	5.05	1.41	6.46
8	a.m.	84.89	4.42	89.31	3.42	5.73	1.54	7.27
	p.m.	84.00	2.90	86.90	3.35	7.37	2.37	9.74
	Total	84.50	3.75	88.25	3.39	6.45	1.91	8.36
9(a)	a.m.	87.18	5.27	92.45	1.67	4.08	1.81	5.89
	p.m.	94.28	2.25	96.53	1.11	—	2.36	2.36
	Total	90.54	3 84	94.38	1.40	2.15	2.07	4.22
9(b)	a.m.	82.66	7.64	90.30	3.97	4.33	1.39	5.72
	p.m.	82.60	9.91	92.51	4.95	—	2.54	2.54
	Total	82.63	8.72	91.35	4.44	2.28	1.94	4.22
10	a.m.	82.00	6.27	88.27	6.79	3.83	1.11	4.94
	p.m.	79.77	6.96	86.73	6.94	5.81	.51	6.31
	Total	80.99	6.58	87.57	6.86	4.73	.84	5.57
11	a.m.	94.32	1.37	95.69	.64	3.67	—	3.67
	p.m.	92.22	1.60	93.82	.66	4.24	1.28	5.52
	Total	93.40	1.47	94.87	.65	3.92	.57	4.49
12	a.m.	81.92	7.15	89.07	4.28	5.46	1.18	6.64
	p.m.	91.43	—	91.43	1.57	5.50	1.50	7.00
	Total	86.08	4 02	90.10	3.10	5.48	1.32	6.80
13	a.m.	85.72	4.00	89.72	2.69	7.59	—	7.59
	p.m.	89.10	2.03	91.13	1.37	6.15	1.35	7.50
	Total	87.26	3.10	90.36	2.09	6.94	.61	7.55
14	a.m.	87.73	7.19	94.92	.81	4.27	—	4.27
	p.m.	90.83	4.66	95.49	.65	3.86	—	3.86
	Total	89.37	5.85	95.22	.73	4.05	—	4.05

(continued overleaf)

Fig. 10. Analysis of productive and non-productive time.

(continuation of Fig. 10)

Operation No.	Period of Day	% PRODUCTIVE TIME Direct Work	% PRODUCTIVE TIME Ancillary Work	% PRODUCTIVE TIME Total	% NON-PRODUCTIVE TIME Operational Delays	Personal Delays Tea Break	Personal Delays Relaxation and Personal Needs	Personal Delays Total
15	a.m.	65.63	22.74	88.37	2.70	6.70	2.23	8.93
	p.m.	70.99	19.33	90.32	1.13	6.14	2.41	8.55
	Total	68.46	20.93	89.39	1.87	6.41	2.32	8.73
16	a.m.	81.06	1.15	82.21	9.95	6.49	1.35	7.84
	p.m.	79.69	1.61	81.30	11.12	6.24	1.34	7.58
	Total	80.35	1.38	81.73	10.55	6.36	1.35	7.71
17	a.m.	85.41	1.99	87.40	4.07	7.41	1.12	8.53
	p.m.	85.06	1.23	86.29	5.68	6.50	1.54	8.04
	Total	85.27	1.67	86.94	4.75	7.03	1.29	8.32
18(a)	a.m.	94.45	.50	94.95	.68	3.89	.48	4.37
	p.m.	97.58	—	97.58	1.32	—	1.10	1.10
	Total	95.84	.28	96.12	.97	2.16	.75	2.91
18(b)	a.m.	87.81	5.69	93.50	1.36	4.19	.94	5.13
	p.m.	94.44	1.42	95.86	1.98	—	2.15	2.15
	Total	90.76	3.79	94.55	1.64	2.33	1.48	3.81
19	a.m.	43 63	43.85	87.48	3.93	6.02	2.57	8.59
	p.m.	63.04	23.98	87.02	3.01	7.49	2.48	9.97
	Total	53.94	33.30	87.24	3.44	6.80	2.52	9.32
20	a.m.	78.20	3.40	81.60	8.62	7.27	2.52	9.79
	p.m.	69.50	13.61	83.11	6.93	7.31	2.65	9.96
	Total	74.18	8.11	82.29	7.84	7.29	2.58	9.87

18(c)	a.m.	94	—	94	2	4	—	4
	p.m.	93	1	94	1	—	5	6
18(d)	a.m.	89	1	90	2	4	4	8
	p.m.	91	2	93	1	—	6	6
18(e)	a.m.	96	—	96	—	3	1	4
	p.m.	98	—	98	—	—	2	2
18(f)	a.m.	92	—	92	1	4	3	7
	p.m.	85	6	91	2	—	7	7
18(g)	a.m.	93	—	93	2	4	1	5
	p.m.	93	1	94	1	—	5	5
18(h)	a.m.	92	2	94	1	4	1	5
	p.m.	82	11	93	3	—	4	4
18(i)	a.m.	91	3	94	2	3	1	4
	p.m.	86	6	92	3	—	5	5

Fig. 11.

(Extension of Fig. 10)

Fig. 10 records the percentage distribution of productive and non-productive time during the morning and afternoon periods, and over the whole working day, for all the operations studied.

From a combined production and memomotion study involving operators 18 (A) and (B), details of seven other operators, on this work, are tabulated in Fig. 11 (an extension of Fig. 10).

Average figures obtained from activity ratio studies for :

1. this same group of women workers; and
2. a group of male workers engaged in tube drawing (similar to operation No. 19, but in a different factory) are tabulated in Fig. 12.

Examination of these tables and of the original production studies reveals the following general

characteristics in the distribution of time not spent on directly productive work.

ancillary work

Minimum 0% (Operations Nos. 12 (p.m.) and 18(a) (p.m.)).

Maximum 43.85% (Operation No. 19 (a.m.)).

Except for certain activities which occur periodically throughout the work period, there is a tendency for ancillary work to be grouped at the beginning and end of each work period.

operational delays

Minimum 0.40% (Operation No. 2(b) (a.m.)).

Maximum 11.12% (Operation No. 16 (p.m.)).

Where these occur, they are concentrated at the beginning and end of each work period.

personal delays

Minimum (no tea break) 1.10% (Operation No. 18(a) (p.m.)).

Maximum (including 7.49% tea break) 9.97% (Operation No. 20 (p.m.)).

Except for the customary tea break during morning and afternoon shifts (which was, in the majority of cases, of longer duration than the time officially allowed by the companies concerned) there is a slight tendency for personal delays also to occur towards the beginning and end of the work periods.

analysis of output curves

From the preceding section, it is apparent that a graph of time spent productively at intervals throughout the work period would — but for the interruption of the tea break — exhibit the "saddle-back" form usually associated with the "typical" output curve due to the grouping of ancillary work, operational and personal delays at the beginning and end of each work period. Examples of such graphs are given in Fig. 13.

Charts showing graphs of the periodic distribution of productive and non-productive time, adjacent to graphs of output rates for the same periods, indicate that the output curve reflects the curve of directly productive time (see, e.g. Fig. 14).

Scatter diagrams of output rates and percentages of time spent productively confirm this relationship (see, e.g. Fig. 15).

From this it follows that :-

1. output per hour of actual working (productive) time remains constant throughout the work shift.

Earlier in this thesis, it has been shown that :-

2. operation and element times remain constant within close limits throughout the work shift; and that

3. operator's working pace, as assessed by time study observers, remains constant throughout the work shift.

This evidence confirms what is apparent from, e.g. Fig. 14, namely, that the cause of the saddle-back output curve is the distribution characteristics of ancillary work and non-productive time, and not the rise and decline of operator performance during the work cycle.

It may be argued that there would or might be a falling-off in performance during the work cycle if these delays, some voluntary and some involuntary, did not occur. Examination of the curves, however,

(1) *Laundry Press: (Operation No. 18) 9 Operators*

	% Readings	
Productive Work	91.0	
Operational Delays		
(Waiting for work)	0.5	
Ancillary Work		
(Booking work)	2.5	
Personal Delays		
Operator away from job ...	3.4	(official "Tea Break"
Talking, drinking, etc. ...	2.6	3.3% excluded)
	100.0%	

(2) *Tube Drawing: 8 Operators*

	% Readings	
Productive Work	57.2	
Operational Delays	3.3	
Ancillary Work		
(Servicing)	35.4	
Personal Delays		
Operator away from job ...	1.7	(official "Tea Breaks"
Relaxation, talking	2.4	5.0% excluded)
	100.0%	

Fig. 12. Activity ratio studies.

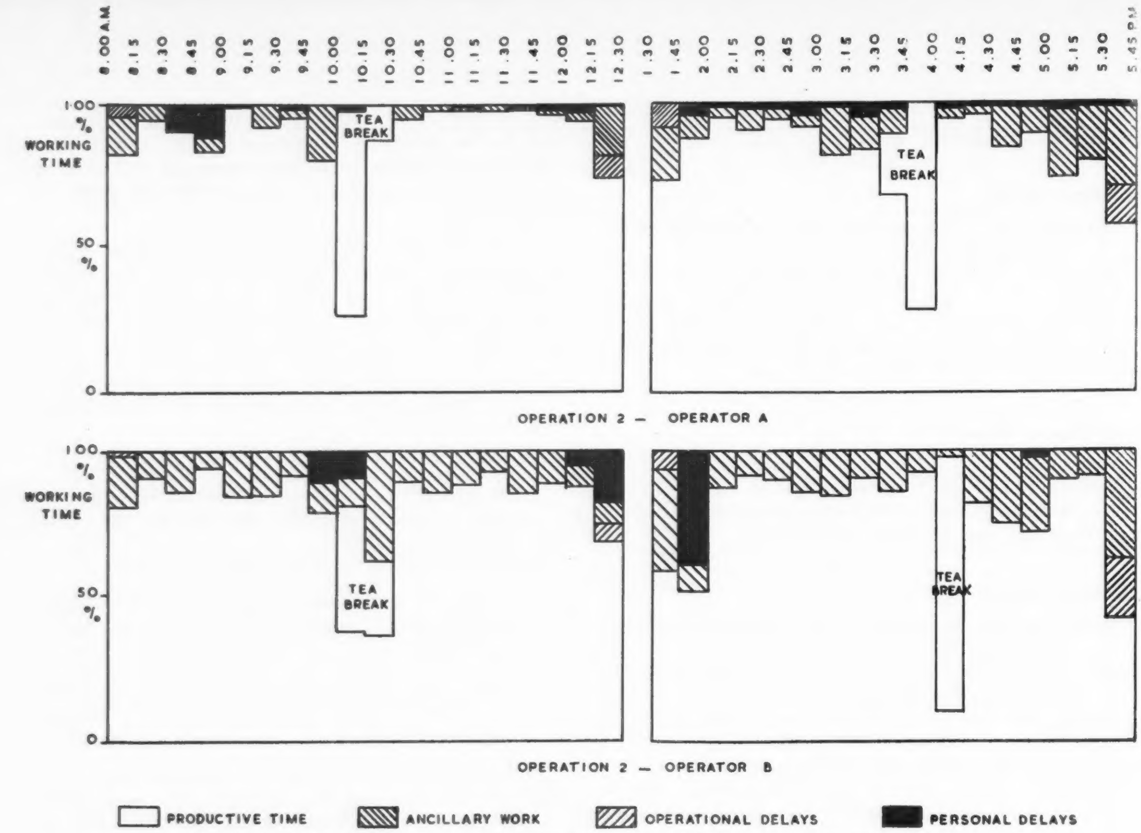


Fig. 13. Periodic distribution of productive and non-productive time — operation No. 2.

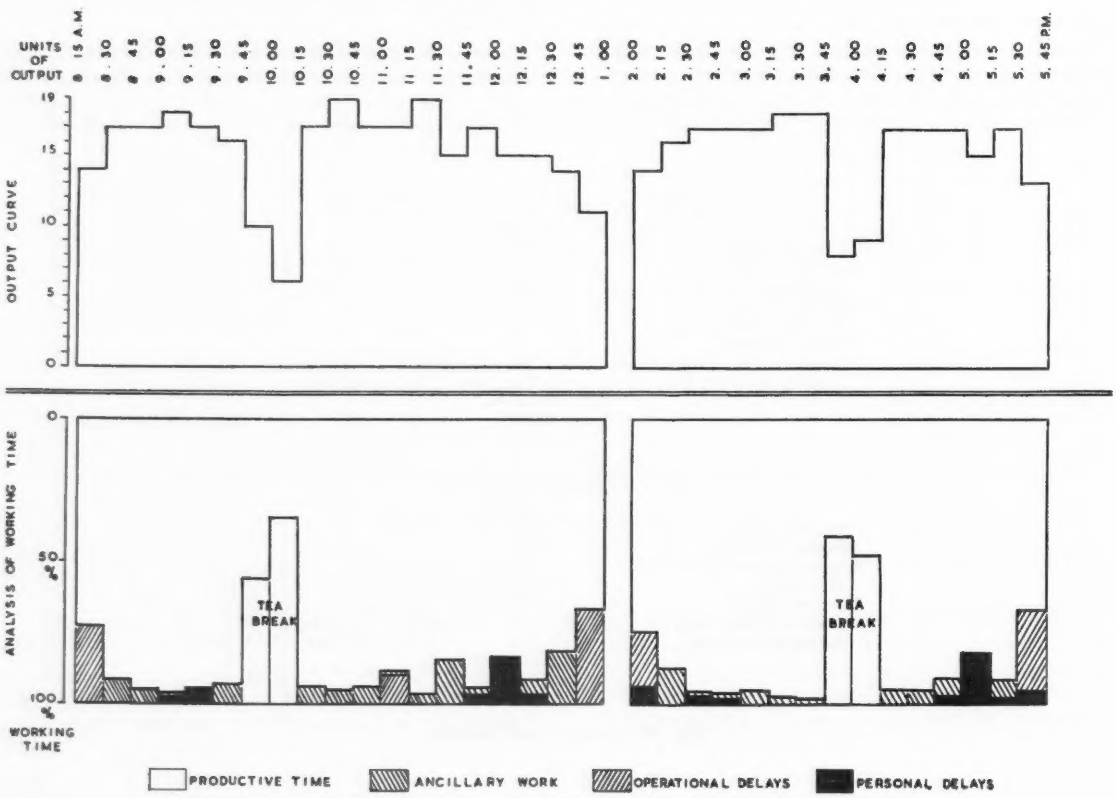


Fig. 14. Comparison of output curve and productive time curve — operation No. 8.

reveals that when little time is lost by reason of delays the output curve flattens out, for the consistency of the operator's working pace is maintained.

comparison of results with company practice

Fig. 16 records the analysis of non-productive time (less the official tea break) for operations Nos. 7, 8, 14, 15, 16 and 19, extracted from Fig. 10, together with the time study allowances actually awarded for these operations.

Comparison of these figures indicates :-

1. that the C.R. allowances given are greatly in excess of the time actually attributable to " personal needs" or "compensating relaxation"; and
2. that ancillary work is inadequately catered for in the allowances given.

It would appear, therefore, that, in the case of the operations studied, about the right amount of allowance was given, but for the wrong reasons!

This is, of course, unsatisfactory, since the allowed time values are liable to become progressively inaccurate wherever changes are made which reduce or increase the amount of unrecognised ancillary work performed during the shift by the operator.

It is a much sounder practice to measure the amount of ancillary work involved, using appropriate methods of work measurement, and to make an exact allowance as required in each case.

to be concluded

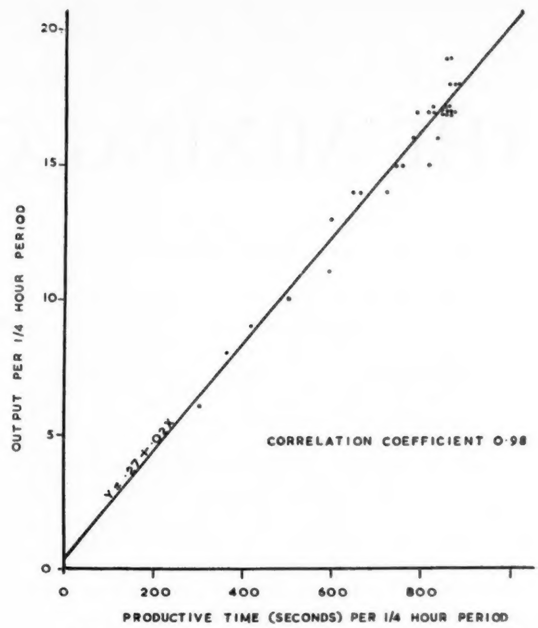


Fig. 15. Scatter diagram — operation No. 8.

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66. Dudley, N. A. " Output Pattern in Repetitive Tasks." Ph.D. Thesis; see Appendix 'D'—" Frequency Diagrams of Operation Times ".
67. Dudley, N. A. Ibid, see Appendix ' E ' — " Motion Pattern Variability ".

Production Study Analysis (Percentages)	OPERATION					
	No. 7 Polish Top Cap	No. 8 Polish Burner Guard	No. 14 Drilling Op.	No. 15 Bulge Tube	No. 16 Mould Casting	No. 19 Tube Drawing
Ancillary Work	5.39	3.75	5.85	20.93	1.38	33.30
Operational Delays	3.18	3.39	0.73	1.87	10.55	3.44
Personal Delays	1.41	1.91	—	2.32	1.35	2.52
Extra Time taken at Tea Break	0.95	2.35	0.05	2.24	1.36	1.80
Total	10.93	11.40	6.63	27.36	14.64	41.06
Time Study Allowances Awarded						
Contingencies (Preparation Time and Ancillary Work)	—	2.50	—	8.50	—	10.00
C.R. Allowance including " Personal Needs " Allowance	15.00	15.00	8.00	20.00	25.00	35.00
Total	15.00	17.50	8.00	28.50	25.00	45.00

Fig. 16. Comparison of production study analysis with company practice.

THE MIXING OF CONCRETE

by C. B. ABBEY, A.M.I.Mech.E., M.I.Prod.E.

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THIS Paper is intended to give a general impression of the important features of concrete mixing.

There are many variables in concrete materials or aggregates, and various means have been used to classify and sort them so that the engineer may use them with confidence for a specified mix.

Concrete is used for many purposes, such as foundations, dam walls, beams, floors, and in pre-stressed form for structural work. It has become the practice for the architect or engineer to specify the types of concrete to suit the particular job. These types require different treatment in the way of mixing, so there are various types of mixing machines available.

Starting with the ingredients, or aggregates, as they are usually called, there are four items used in a concrete mix:

1. cement ;
2. sand or fine aggregate ;
3. coarse aggregate ;
4. water.

A dictionary definition of cement is "An adhesive substance capable of uniting fragments or masses of solid matter to a compact whole". This may apply to many different adhesives, but the cement for use in concrete is known as calcarious cement, so called because of its calcium oxide or lime base.

Fig. 1. The standard 3½ size tilting-drum mixer, which is made as light in weight as possible for easy transport to sites where a small amount of concrete is required.

Lime has been used as a cement or mortar right back into antiquity. The Romans used to burn limestone to drive off the carbon dioxide, leaving the lime for mortar. The temperature at which this was done must have varied very much and the impurities that were with the limestone also affected the finished lime.

It was established that limestone from certain places was better than that from others, but no real experimental work seems to have been carried out until John Smeaton was given the job of rebuilding the Eddystone Lighthouse in 1756. He carried out quite a range of experiments using materials from various sources and countries, and was able to find a lime in Dorset which exactly suited his requirements. This lime was considered to be one of the best cement limes for many years after the Eddystone Lighthouse was completed. The reason for this was probably that it had a clay and silicon sand content.

establishment of standards

The Germans seem to have been the first to establish standards of quality of cement, in 1877, the English standards being first published in 1904. The Americans and the French were also doing good experimental work.

The cements were now becoming similar in characteristics to our present-day cement. They were being called Portland cement because the resulting concrete was white in colour and said to resemble Portland stone.

As the years passed, machinery and equipment improved until the careful chemical control of the ingredients, coupled with an accurate temperature in the burning, followed by good grinding and sieving, have made the present-day cements very uniform in all their characteristics.

At present, in the U.K., there are three main grades of Portland cement in common use. They are the standard Portland cement; the rapid-hardening cement; and the quick-setting cement.

These cements contain the same ingredients, i.e. approximately 64% lime, 23% silicon oxide, 4½% aluminium oxide, and 3% iron oxide. These are commercial gradings and contain small quantities of other chemicals up to 100%.

The mixing of the ingredients is wet and very thorough and the burning takes place in kilns at an accurately controlled clinkering temperature. The burning action combines the calcium and silicon, also the aluminium and silicon, among other things, and evaporates the water of crystallisation, leaving an anhydrous mass.

The rapid-hardening cement differs only in that it is rather more thoroughly mixed and more finely ground.

Quick-setting cement contains about 2% of calcium chloride, added by the manufacturers. This makes it set off very quickly with a generation of heat which is useful in frosty weather. It has a tendency to attack steel reinforcement and is the subject of some experimental work to overcome this difficulty.

A fourth type of cement is the high alumina cement, which has the same ingredients as Portland cement, but in different proportions. These are approximately 35% - 40% aluminium oxide; 35% - 45% calcium oxide; 5% - 10% silicon oxide; and 5% - 10% iron oxide. The burning temperature is higher and the chemical action different. The main difference to the engineer is the very rapid rate of the development of strength; in 24 hours it approaches its final strength.

There are, of course, quite a number of cements which have not been discussed, such as the gypsums, the blast-furnace cements, the supersulphates, magnesium oxychlorides and many special purpose cements.

The sand is all that part of the aggregate which will pass through a $\frac{3}{16}$ in. mesh. It must be sharp and have very little fine sand. There must be no organic matter, clay or other soft materials and it must not absorb much water. Modern sand quarries, who supply sand for concrete, wash it carefully and, in the process, extract the very fine particles. Porous aggregates suck the water from the mix and affect the chemical action.

Sands for concrete are specified by the amount of each size of particle contained in a standard quantity

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Mr. Abbey, who is Chairman of the Newcastle Section of the Institution, and also Northern Regional Chairman, was elected to the Section Committee in 1946, soon after he was elected to membership of the Institution.

Fig. 2. A standard $3\frac{1}{2}$ size tilting-drum mixer, arranged with pneumatic wheels for towing behind a road vehicle.

of sand — this is called grading. For the grading of sand a nest of six sieves is used, in the following sizes: 100 mesh; 52 mesh; 25 mesh; 14 mesh; 7 mesh; and $\frac{3}{16}$ in. mesh. The sieves are often circular in shape and each about 50 sq. in. in area. They are made to stand one on top of the other, the largest mesh being at the top.

The number of the mesh shows its size, e.g. a No. 100 mesh sieve means that each inch of length is divided into 100 parts which include the space and the wire. (There is a British Standard for these mesh sizes.) In the finer mesh sizes the wire is about half the size of the hole. In this way a 100 mesh sieve has holes which are about six thousandths of an inch square.

The grading is accomplished by putting a measured quantity of sand into the top sieve and riddling until each sieve has retained only the parts which were too big to pass through the mesh. The amount of sand retained on each mesh is measured and taken as a percentage of the original amount put in the top sieve. This is usually shown as the percentage of sand which will pass each size of sieve, and means adding together the amounts on each sieve below the size being considered. The result of testing a typical river sand might be 100% passing $\frac{3}{16}$ in. mesh; 86% passing No. 7 mesh; 71% passing No. 14 mesh; 46% passing No. 25 mesh; 10% passing No. 52 mesh; and none passing the 100 mesh.

testing for impurities

Sand should also be tested for impurities such as organic matter and silt. For this a clear glass 12 oz. graduated medicine bottle is used. The bottle is filled to the $4\frac{1}{2}$ oz. mark with the sand to be tested. A 3% solution of sodium hydroxide is then poured into the bottle until it reaches the 7 oz. mark. The bottle is now stoppered and shaken vigorously, and allowed to stand for 24 hours. By this time the sand will have settled to the bottom, the silt will be resting on the sand and the organic matter will show in the amount of discolouration of the liquid.

Coarse aggregates should be made up of the harder and stronger rocks, such as granite, dolerite (of which whinstone is one), basalt, limestone and the harder sandstones. Gravels usually contain a mixture of the harder rocks, because the softer pieces have already been crushed into sand.

If crushed rock is being used, it must be properly treated so that the fine dust is removed, as this would weaken concrete by preventing the cement from making contact with the aggregate.

Dried coarse aggregates should not absorb more than 5% by weight of water after being immersed in water for 24 hours. Some contracts allow a relaxation of 10% absorbtion for certain work.

The coarse aggregate is also sieved and checked for the amounts held by each size of sieve, and $\frac{3}{4}$ in. aggregate is often tested with a set of sieves in three sizes — $\frac{3}{4}$ in., $\frac{3}{8}$ in. and $\frac{3}{16}$ in. Good aggregate would have all passing the $\frac{3}{4}$ in. mesh, 66% held on the $\frac{3}{8}$ in. mesh and the balance on the $\frac{3}{16}$ in. mesh.

The calculations and methods of working out the gradings for specific mixes is too complex a subject to be discussed here, but is very clearly described in the Road Research Technical Papers published by the Department of Scientific and Industrial Research.

use of lightweight aggregates

In recent years lightweight aggregates have been used for certain purposes. Pumice is one of the few natural lightweight aggregates, although there are a number of artificial ones, such as exploded burnt clay, vermiculite and various aerated concrete materials. These have special applications in insulation, soundproofing and blockmaking for the partition walls of large buildings where weight affects the steel structural sizes.

These aggregates require special mixing and usually have to be thoroughly soaked in water before being put in the mixer.

The last ingredient of concrete is the water. It is very important that clean fresh water is used. Any organic matter is very bad in concrete and certain salts affect the cement. On the whole, water which is suitable for drinking is suitable for concrete.

When water is added to cement a chemical change takes place and new compounds form into crystallised masses. The crystals become embedded into the roughness of the aggregates which, when set, have a mechanical hold on each other. In the process of mixing concrete the aim is to coat every particle of sand with cement cream and every particle of coarse aggregate with the coated sand. It will be seen that if particles of sand are left uncoated and touching each other, they will not be cemented together, which could leave a weakness in the concrete.

In good consolidated concrete the pieces of coarse aggregate should be all in contact with each other and the spaces left by the irregular shapes must be completely filled by the smaller particles and fine aggregates, so that there are no voids or air-holes.

These considerations play a large part in the types and sizes of aggregates to be used, together with the thickness of the finished concrete slab. In very heavy concrete blocks such as are used in heavy foundations and dams, the coarse aggregate may have pieces as large as 2 in. - 3 in., but in floors, thinner slabs and very often reinforced concrete, the coarse aggregate is commonly restricted to $\frac{3}{4}$ in.

importance of water : cement ratio

One of the main factors in the strength of concrete, given reasonable aggregates, is the water : cement ratio, that is, the weight of the water divided by the weight of the cement in a batch. The less water used, the stronger the concrete, as long as there is sufficient water to hydrate the cement. Excess of water evaporates as the concrete sets and leaves porosity in its place.

A water : cement ratio of .35 would make a strong concrete but it would be difficult to mix and very difficult to place. The term "workability" is used to discuss the ease with which concrete can be placed and tamped into a solid mass. Generally a compromise has to be arrived at between the strength and workability of the concrete. In the jobs of less importance, workability wins.

The term "workability" denotes the ease with which concrete may be compacted, that is, the elimination of the trapped air and voids. An apparatus has been designed to enable the engineer to work out the compacting factor of any mix. It consists of two inverted frustrums of cones, one fixed vertically above the other and a cylindrical mould under the lower one. The test is made by filling the top cone with the loose concrete to be tested, releasing it and allowing it to fall the specified distance into the second cone, which is smaller than the top cone. The bottom of the second cone is removed and the concrete falls a further specified distance into the mould, which has a smaller volume than the second cone. Thus a certain known amount of work has been done on compacting the concrete. The excess concrete is cut off the top of the mould and the compacting factor is calculated by dividing the observed weight of the concrete in the mould by the weight necessary to fill the mould without air or voids, this latter weight being obtained from the known specific gravity of the materials. The use of the compacting factor is in the comparison of two different mixes.

Practical means of working to a correct water : cement ratio are rather difficult to arrive at because of the included water in wet aggregates. One method is to dry and weigh a cubic foot of aggregate and then weigh a cubic foot as delivered. The difference should be the included water. It is obvious that a shower of rain will add water to the aggregate and a spell of warm sunny weather will tend to dry it. These conditions make it necessary to keep a check on the concrete as it is delivered from the mixer.

A simple method of comparing the water : cement ratio of mixed concrete is by making a slump test. For this a hollow metal frustrum of a cone is used, measuring 12 in. deep, 4 in. inside diameter at the

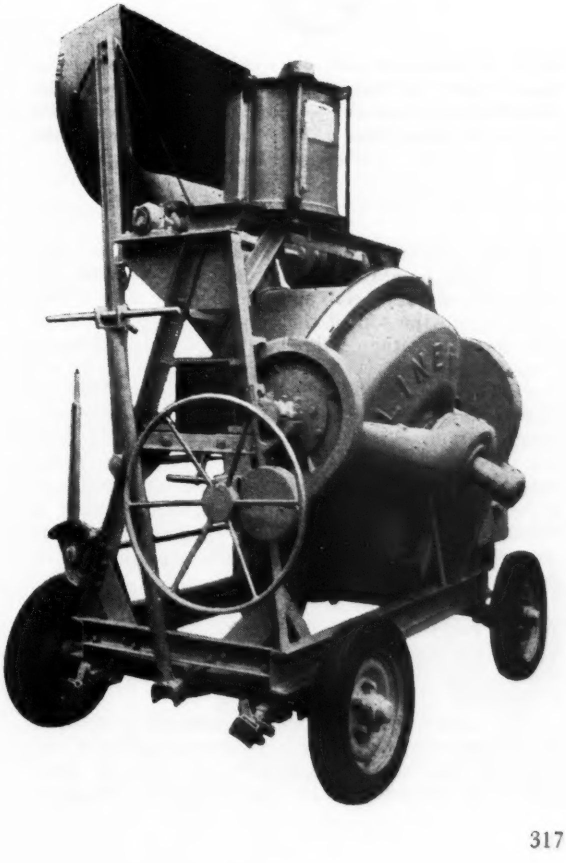

Fig. 3. A standard 7 size tilting-drum mixer seen with the loading hopper in the loading position. The lever on the left is for operating the lifting and lowering of the loading hopper. The hand wheel is for tilting the drum from loading to mixing and discharging. Machines are usually transported with the hopper lifted in this manner.

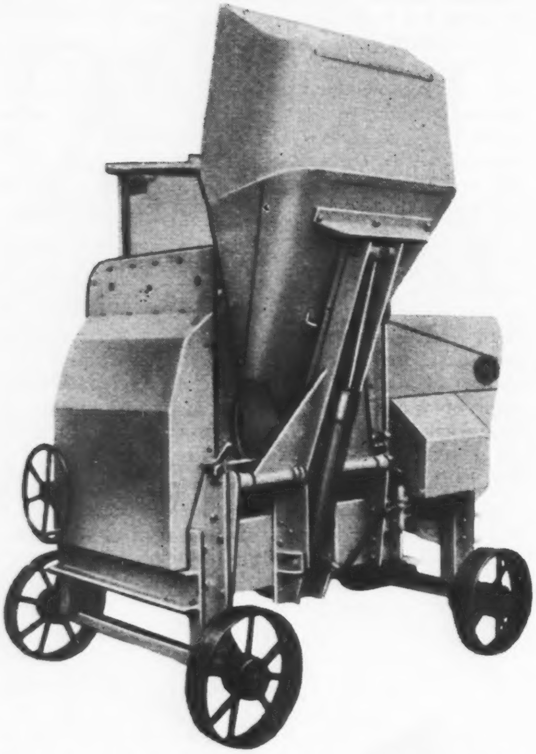

Fig. 4. A standard 7 size rotary drum mixer showing the hopper raised. In this instance, the hopper is raised by hydraulic means controlled by the small lever at the opposite end to the hand wheel. This hand wheel controls the discharge chute.

top and 8 in. inside diameter at the bottom, and with lifting handles at the sides. The base of the cone rests on a level slab and the concrete to be tested is filled into the top of the cone to a depth of 4 in. The concrete is then rodded 25 times with a pointed ⅝ in. diameter steel rod. The next two 4 in. layers are filled into the cone, each being rodded 25 times. The concrete is then levelled off at the top of the cone, without pressing it down. The cone is now lifted vertically off the concrete, which will settle down and distort. The height of the concrete mound is then measured from the slab and this distance is deducted from the original 12 in. height of the cone. The difference in height is called the amount of slump of that particular mix.

With a low water : cement ratio there will be only a small amount of slump. A very wet concrete will spread out into a hemispherical mound. In general, good strong concrete should not have more than a 6 in. slump.

The water : cement ratio is considered in relation to the means to be used for the consolidation of the concrete. Low water : cement ratios may be used where the concrete is to be consolidated by vibration. This jostles the larger aggregates until they work themselves close together, thus squeezing out the excess cement cream which will rise to the surface of the block and can float off the top. The air is also forced out by vibration. Where the concrete is being contained by shuttering, the vibrating unit is usually fixed to it, but in the larger blocks a portable poker type of vibrator is used.

In the wetter concretes rodding is very often used to ease out the voids. A metal rod is simply pushed into the soft concrete and moved up and down in a sort of tamping action. A flat or shaped tamper is used to finish off the top surface.

Another type of concrete in common use is cement mortar for building work. This concrete has entirely different characteristics, because smoothness and plasticity are the main requirements. Fine sand and cement are the ingredients and quite often some powdered hydrated lime is added to the mix to improve the smoothness. To make good mortar a certain amount of work must be done on the mix, either by milling it with rollers or impacting it with mixing blades. This helps to give the intensive mix necessary to mix fine aggregates. Mortar is usually rather a wet mix, which helps to distribute the cement.

types of mixer

For mixing concrete there are five types of mixer in common use in Britain. They are the tilting-drum mixers for small batches of the wetter mixes; the rotary or closed drum mixers for the larger batches of wet mixes; the roller-pan mixers for mortars and some of the pre-cast concrete; the paddle mixers for some of the drier mixes; and the revolving pan and star mixers for the better types of mix where the water : cement ratio is low.

The numbered size of a concrete mixer is the number of cubic feet of mixed concrete expected per batch, and the tilting-drum range is from 2 cubic feet to 10 cubic feet, with one or two firms making a 14 cubic feet mixer.

The 2 cubic feet and 3½ cubic feet mixers are usually loaded by hand. The 5 cubic feet and upwards are usually made with a mechanically operated hopper to speed up the loading (Figs. 1, 2, and 3).

The drum of these machines is shaped like half a sphere at the bottom with a truncated cone on the top or outlet end. The drum is mounted in a rocker arm so that the vertical axis may be turned from the vertical to a steep angle on either side for loading, mixing and discharging. The bevel drive to the drum is taken through the swinging centre of the rocker arm. For good mixing the speed of the drum is critical and arrived at by experimental tests. The periphery speed of the outside of the drum usually works out at about 200 ft. per minute, but varies with the shape of the drum, the blades and the mixing angle. The inside volume of the drum is decided by a British Standard and the mixing angle

is arrived at by tilting the drum until the required size of mix, plus 10%, will just not spill out of the mouth while mixing.

Inside the drum, blades are fixed to assist in the mixing. Either two or three equally spaced blades are fixed to the inside of the cone at an angle of about 45°. The action of mixing is done while the axis of the drum is nearly horizontal. As the drum revolves the concrete is lifted by the blade and part of it slides back down the angle of the blade, towards the base of the drum. The excess which is above the level of the blade drops down on to the cone until it is caught up by the next blade. This mixing causes an interchange of the aggregates from the front to the back of the drum, where it settles down and comes forward again. Some makers provide blades at the base of the drum to help in pushing the mix forward.

This type of mixer is particularly suitable for mixes of about .5 water : cement ratio and wetter, because no work is done on the mix other than that carried out by its own weight slowly turning and rubbing against itself. The cement is turned into a cream which coats the aggregates as they turn in the drum. Drier mixes may be mixed in these mixers, but great care is required to prevent the concrete sticking to the drum, as when this happens to any extent the machine must be stopped and cleaned or it becomes clogged and mixes badly. To help to prevent this sticking most of the water is put into the drum before any aggregate is added.

The power unit is usually a petrol or diesel engine, so that the machine may be used in the field where no electric power is available.

the rotary drum mixer

The rotary drum mixer is made in various sizes from 10 cubic feet upwards. In America, machines are used which take very large batches indeed.

The drum is cylindrical in shape, with the ends closed except for a comparatively small opening in the centre of each for loading and discharging (Figs. 4 and 5).

There are two different types of blading used in different makes of these machines. In the first type, there are a number of evenly spaced scoop-shaped blades which are fixed radially to the inside of the cylinder. They are kept clear of the drum to allow the water to wash round and take away any concrete, which may be left sticking to it from a previous batch. As the drum revolves, the scoops pick up the concrete and carry it upwards until it slides off and drops to the bottom of the drum again. There are side cheeks on the scoops which have varying angles to deflect the mix to different sides of the drum, and give an interchange of the materials to help in mixing it. The discharge takes place by swinging a curved discharge blade inside the drum so that the concrete which has been lifted by the scoops is dropped on to the discharge blade, which is

Fig. 5. A standard 10 size rotary drum mixer with the discharge chute in the discharge position. Here, the operation is by lever instead of a hand wheel.

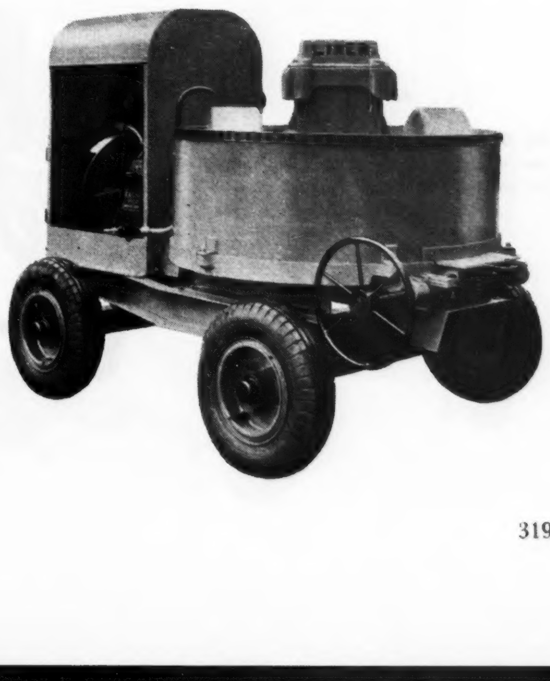

Fig. 6. Elevation view of a roller pan mixer. Although this photograph shows pneumatic tyred wheels, standard machines are fitted with steel rimmed wheels. The hand wheel is for operating the door.

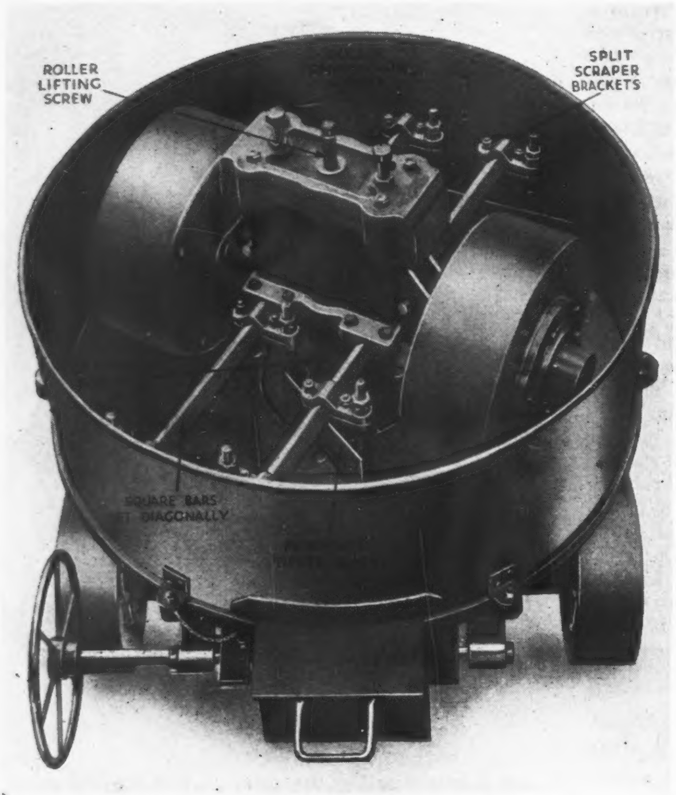

Fig. 7. View of the inside of the pan of the roller pan mixer. The diagonally set bars are so arranged to prevent aggregates lodging on the bars when loading.

Fig. 8. Portable type of revolving pan and star machine. Space is provided underneath the machine so that a dumper may be used to receive the mixed concrete.

down-sloping outwards and directs the mix into a receptacle, to be taken away for placing.

The second type of blading also has evenly-spaced scoop blades at the discharge side of the drum, but there are sharply-angled blades at the inlet side, which direct the concrete into the scoops as the drum lifts it. Sometimes the discharge blade is used in the mixing by being tilted with its downslope inwards so that as the mix is dropped on to it, it is thrown back across the drum on to the angled blades, giving a side-to-side interchange of the mix. The discharge takes place by angling the discharge blade to direct the mixed concrete outwards.

For good mixing the speed of the drum is critical and the outside periphery speed is approximately 200 ft. per minute. Again, this is affected by blading and drum shapes and final mixing speeds are decided by experiment.

The mix is put into the drum by a tilting loading hopper and the water is delivered through a large pipe by gravity from an accurately calibrated water tank. As in the tilting drum mixer, the drum is kept cleaner if the majority of the added water is put into the drum before the other aggregates.

This type of mixer is used for the wetter mixes. There is more work done on the mix by the greater fall of the aggregates inside the drum than in the tilting-drum mixer. There is, however, a tendency for the mix to stick to the drum when it is used for the drier mixes.

The roller pan or mortar mixers have open pans which are comparatively shallow and of large diameter. There is a central revolving headstock which carries round the rollers and the mixing blades. The rollers are hollow cast iron and not intended for heavy crushing. They may be adjusted in height so that they may rest on the pan base, or be raised up 2 in. or 3 in. for kneading semi-dry mixes (Figs. 6 and 7).

There are bars at right-angles to the roller axis to which blades are fixed. These are placed at an angle to deflect the mix under the roller track, which in turn flattens it and spreads it out again. The blades are adjustable for height and are arranged to just skim the pan base.

There is an outlet door in the pan base for the mix to be discharged.

In these mixers the aggregates are put in dry and mixed together before any water is added. For mortar when the rollers are on the pan bottom, the rollers squeeze the mix together so that every particle of sand is forced into contact with the cement, making the concrete smooth and plastic. The scrapers turn over and deflect the mix and prevent it from sticking to the machine. For the semi-dry mixes the rollers are raised to give a kneading action on the mix without crushing it and an extra blade is fitted in the line of the roller track to prevent the mix from caking on the pan base, and also to help in the discharge.

It will have been seen from the previous description that these mixers are suitable for any water :

Fig. 9. View from the other end of a machine similar to that shown in Fig. 8.

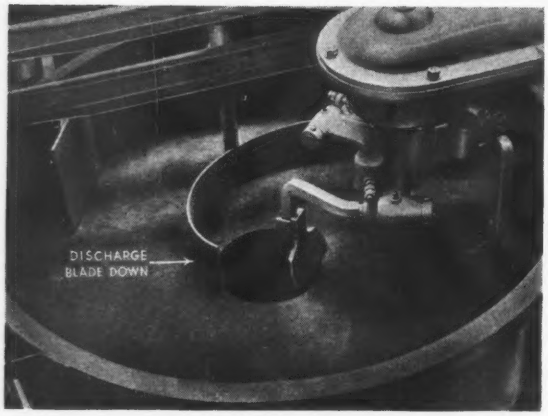

Fig. 10. View inside the pan of a revolving pan and star mixer. The door is shown open and the discharge blade resting on the pan. When the door is closed, the discharge blade lifts about 6 in. to be clear of the mix. The side scraper is seen on the left and the star on the right.

cement ratio, but would not be economical or suitable for the rough wet mixes.

paddle mixers

Paddle mixers can have either one or two rows of paddles. In the single row machine, the pan is shaped like half a cylinder with the ends extended parallel above the centre line. The paddles are fixed to rigid arms which are in turn fixed to a revolving shaft. The blades at the end of the machine are angled so that the mix is deflected towards the centre of the pan, and the central blades are turned to deflect the mix outwards, giving an interchange in the concrete mixed.

The double-row paddle mixers have two parallel shafts running in opposite directions and the paths of the blade tips overlap each other. This pan in section is shaped like a letter 'W' with rounded bottoms.

The concrete is discharged from the mixer by the removal of part of the base for the full length of the mixer, which allows the mix to fall on to a chute which delivers it to the side of the machine.

These mixers may be used for wet or dry mixes but the size of the aggregate is limited to the clearance between the blades and the pan body.

revolving pan and star mixers

The revolving pan and star mixers are rather more expensive in the initial price, but really do combine the drier mixes (Figs. 8, 9 and 10).

The pan is revolved with an outside periphery speed of approximately 200 ft. per minute and the star, which covers half the diameter of the pan, runs at four to five times the number of revolutions of the pan.

There are two types of mixer. In one type, called the counter-current or contra-flow mixer, the star revolves in the opposite direction to that of the pan; and the other type, where the pan and star run in the same direction, is called the cum-flow mixer.

The star has three blades which are angled to deflect the mix and also to lift and turn the mix in a sort of ploughing action. These blades are adjusted to just skim the pan base and the arms carrying them are sprung so that, if any material jams under a blade, the arm is forced back and the material released.

In the contra-flow mixer the star has a high impact speed at the pan rim and a much less relative speed at the centre. This causes the mix to be thrown from the pan side and to pile up in the centre.

In the cum-flow mixer the relative speed is less at the pan rim and there is a more uniform speed all over the mixing area. The mix is more evenly spread out.

Both these machines give a very good mix because all the aggregate in the pan is brought under the star at every revolution of the pan (**Fig.** 11).

Much work is carried out on the mix by the impact of the blades, which give a sort of squeezing-rolling-over action and there is a very good interchange of the aggregates all over the pan. Another very important point is that these mixers mix the materials dry before any water is added, and then continue to mix them efficiently after the addition of the water. They may be used for any water : cement ratio from .2 upwards, or, of course, for dry mixes where there is no added water.

These machines can be adapted readily to fit any mixing scheme, as they have an open pan. The aggregates to be mixed may be raised from the ground to any height, in a loading hopper, or may be fed from a fixed bunker or again by a travelling weighing skip.

The discharge takes place through a centrally-placed removable circular door. In the cum-flow machines a discharge blade is fitted which drops on to the pan bottom when the door is opened. This guides the mixed concrete to the door opening and greatly speeds up the time taken to discharge, while at the same time thoroughly cleaning the pan bottom. There is also a fixed blade just skimming the inside of the pan rim to shave off any concrete which may tend to stick to that.

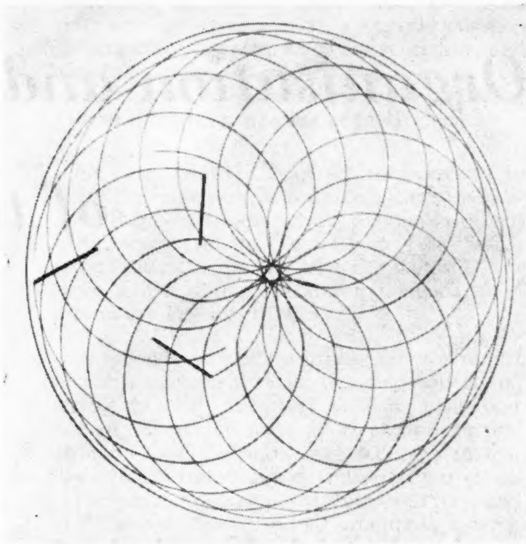

Fig. 11. Diagram of the base of the mixer, showing the continuous path taken by the tip of each blade during one revolution of the pan. The blades are the straight lines on the left of the diagram, and it will be seen that each curve starts at an outside tip of a blade. It may be noted that the curves finish at a different point from which they started, because the blades are arranged so that they do not follow exactly the same path on the second and subsequent revolutions.

There are a number of other types of concrete mixer which are used either for special purposes or for special types of mix, which it is not possible to describe within the confines of this Paper.

To sum up the mixing of concrete, the type of mixer is decided by the type and strength of the concrete called for in the specification. The lower the water : cement ratio called for, the better and more expensive the mixer required to mix it. Additional capital expenditure on mixing machinery can frequently be offset by the use of leaner mixes, thus saving cement and even gaining in the strength of the finished concrete. Good mortar for brick-laying will make both satisfied brick-layers and customers.

A final word on maintenance — soft concrete can be readily washed off a concrete mixer and tools, but if it is left until the next day it has to be chipped off, which is a lengthy business and often damaging to the tools.

HEAD OFFICE POSTAGE

THE greatly increased postage rates over the last year or so have created a heavy burden on Institution expenditure — for example the first increase, which was made on 1st January, 1956, resulted in additional annual expenditure of £3,000 on postage of the Journal alone!

In order to counteract this, the staff at Head Office is continually exploring new ways and means of affecting economy in postage. Many members, too, are very helpful in the fact that they draw attention to incidents of apparent wastage. In many cases, members refer to incidents where they have received two letters from Head Office in the same post, which they think could have been included in the same envelope, thus making a saving in postage. All these cases are studied very carefully and in some cases apparent wastage could have been avoided. However, it must be remembered that when circular letters are sent to members, the envelopes are addressed on an automatic addressing machine and the cost of labour involved in sorting through these envelopes, in order to include a typewritten letter to be despatched the same day in one particular envelope, would be far greater than the cost of the additional postage used.

Constructive criticism from members in this connection is always appreciated and any suggestions for effecting economy in postage will be most welcome. If you should receive more than one communication from Head Office in the same post, it would be of assistance if you would return the actual envelope or wrappings when reporting this matter to Head Office.

Organisation and Management of the Production Unit

a thesis by E. W. DIXON, A.M.I.Prod.E.

an examination of the foreman's place in the modern management techniques

THE objective of this thesis is to re-examine the foreman's place in management, this examination being effected by the advances which modern techniques have made possible in scientific management.

The most common production unit to be found in Britain today is a unit of medium size, i.e. 500 - 1,000 direct employees operating on a batch production programme. It is, therefore, proposed to base the examination on foremen in a production unit of this size and type.

1. Management as a team, its moral responsibility, and the foreman's place in this team

(a) The art of management has been defined as "directing the activities of the workpeople to the achievement of a preplanned programme", the operative words inasmuch as they affect this thesis being "directing", "activities", and "workpeople".

(b) Management has a moral responsibility towards employees which is not generally recognised by the workpeople themselves, and a manager who is not making decisions on a basis of firm moral judgment is not wholly fulfilling the requirements of his position.

Whilst this thesis does not set out to examine management in detail, it will be accepted that a foreman is his manager's representative on the shop floor, and that if he has to take his place as part of the management team he must have a very clear understanding of the manager's responsibility towards those employees for whom he has direct responsibility.

(c) This means that all supervisors must be regarded as responsible members of the management team. They should be carefully trained and selected, should be consulted and kept fully informed about company policy and procedure, and must be given adequate status and prospects of promotion.

Here are principles which will be accepted by all but the most conservative managements. The difficulty usually arises in their application and *acceptance by the foremen themselves.*

A typical organisation chart (see Appendix 1) will show lines linking levels of management including foremen in various functional responsibilities. What it cannot show is an organisation as a team with the Works Manager as a leader — a leader who regards every foreman in his team as a person with individual likes and dislikes, with problems of adjustment to those with whom he comes into contact, with fears both real and fancied, and most important (because they should have been selected for their qualities of leadership above all else), with their own firm ideas of how their departments and the company should be run.

(d) Foremen will not believe that they are being fully regarded as part of management, if they are not treated as "part" in the widest sense, and kept as fully informed as possible of company policy.

(e) Being a foreman has, in the past 20 years, lost much of its old status, a status which was based on power (say that of final discharge), and this status must be returned if the foreman is to make his full contribution towards the company's productivity and general well-being. A more lasting and valuable status will be achieved if it is based on :

(i) confidence in management backing of his decisions;

(ii) knowledge that his own selection was in preference to others who would have liked to be selected;

(iii) a full understanding of the company policy and his operatives;

(iv) a feeling that promotion to a higher grade is still available;

(v) enjoyment of management privileges, i.e. holidays, sickness benefits, pensions and, perhaps most important, not "clocking on".

(f) We see, therefore, a management pattern emerging, of the team fixing its activities towards the achievement of a plan with foremen taking their full part in the team as responsible and fully-informed members, who share and interpret to their own people the Works Manager's care and regard for his employees, knowing they have his full confidence and will secure his backing in all decisions they make, because those decisions will be based on a full knowledge and understanding of company policy.

2. Co-ordination of functions and communications

(a) Probably the greatest recognisable loss of status suffered by foremen is that of not being able to "discharge at will"; but this only illustrates in one small way the changing conception of the foreman's place in management. This right of the "ultimate" has been taken over by the Personnel Department, and a foreman today would have to present a very firm case before a decision is made.

(b) An examination of the functions covered in any organisation chart of any medium size, or even a quite small company, will reveal that many, 20 years ago, were almost the sole prerogative of a foreman operating in his own department. The foreman of the past would tool, ratefix, and programme his own shop, using labour he had himself engaged and trained. If there was any costing at all, it was done on his own job knowledge, and any welfare arrangements would be the result of a direct approach by the foreman to the Works Manager. Production control on the shop floor would exist mainly in the form of chasers who negotiated with the foreman, and his right of entry to the Works Manager on any aspect of his work, without consulting any other authority, would be unchallenged.

(c) It will, therefore, seem that the number of specialists now used in modern management have reduced the foreman's duties to that of a policeman walking his shop floor, concerned only that his operatives are diligently engaged in activities prescribed by those specialists, and reporting those operatives not meeting the requirements of the specialists to the Personnel Officer for further training or replacement.

(d) This view, whilst it may not be expressed in quite the same way, is commonly held by foremen themselves, who say, "the tool will not work, send it to the Tool Room", or "there is no material, ring the Material Control", or more serious, "this operator is no good, send him to the Personnel Officer".

A foreman in modern management is a part of the management team, servicing and giving service to other members of that team, and one of his major tasks is to ensure the co-ordination of the specialists' work so that it flows freely and efficiently into and out of his department. An example of this would be found in the introduction of a new product in a batch production factory, where the production engineering department would do a layout and rate the job, using space which the foreman could tell them is available, because of his knowledge of the production control demands on his shop, and labour which he can make available because of his co-operation with the Personnel Office (see Appendix 2).

(e) Co-ordination of the major activities to achieve the plan, is, of course, one of the prime responsibilities of a Works Manager, but many of the routine activities, each of which will have its effect, will be controlled by the foreman, and it is in this that he is closest to the Manager, if he understands the plan and accepts freely the place which his own efforts will play in its achievement.

(f) Reference under this heading is so far being made only to co-ordinating other functions. It must also be remembered that a foreman has the duty as a member of a team of co-ordinating the work of his own shop with those of other foremen.

While it is true that a large measure of this inter-shop co-ordination will be the responsibility of production control, a well-trained foreman, acting as a member of a team with other foremen, will always be willing to deal with those exceptions, of which "work requiring rectification" is a good example, which cut across the system, and which, if everyone "works to rule", will hold up the most carefully drawn production target.

(g) It will be seen, therefore, that a vertical line of communication from and to the foreman must be clearly defined, and horizontal lines, by means of meetings, established.

The following suggestions are detailed as immediate requirements, and the meetings should be attended by all foremen :

Company policy meeting. Held at least yearly and when any other change, which may give rise to rumour, occurs. Attended by Works Manager and Works Superintendent.

Production plan meeting. Held at the beginning of each planned period. Attended by Production Controller, Works Superintendent and Production Engineer.

Personnel policy meeting. Held half-yearly. Attended by Personnel Officer and Training Officer.

Training policy meeting. Held half-yearly (may be joined with (3) above). Attended by Personnel Officer and Training Officer.

General foremen's meeting. Held half-yearly. Attended by Works Manager and/or Works Superintendent.

Special meetings to deal with specific problems. Held as required. Attended as suitable.

Cost reviews meeting. Held at end of each cost period. Attended by Cost Accountant, Works Superintendent and Production Engineer.

(*See Appendix* 3.)

(h) There are many valid objections to meetings, but in evaluating these suggestions it should be firmly borne in mind that a foreman who is told some detail by a member of the J.P.C. or a shop steward which he should, by virtue of his being a member of management team, have known first, has lost *in his own eyes* much of his status, particularly as he will have to " cover up " by pretending he already knows.

The importance of making sure foremen are in the picture is emphasised. It is the Works Manager's responsibility, and he cannot shelter behind the fact that he has requested someone else to tell the foreman.

The embarrassment and sense of frustration suffered by foremen because of an omission to give him information before telling the Trade Union is the result of one of the greatest mistakes in modern management; that is, to substitute shop stewards for foremen when communicating with the workpeople. The resultant frustration felt by foremen does much to retard their full partnership in the company's management team.

3. Keeping the foreman's interest in the overall programme

(a) Reference to the overall programme in this heading assumes a production plan which has been, or is being drawn up, to direct the activities of the workpeople in the various shops to meet a single purpose.

Whilst there are organisations which are divided into departments each producing both the piece-parts and the end products, the more usual pattern is that of a number of shops feeding a stores, and the stores feeding an assembly department or departments, who in turn deliver to a warehouse or the shipping bay.

(b) Production plans and schedules are the blueprints which will guide a foreman in carrying out the co-ordinating activities mentioned under section No. 2, and it is, therefore, important that he should :

(i) be fully informed, not only of his departmental programme, but of the general plan; and

(ii) be fully informed of any change of policy which will affect his shop; for example, the machine shop foreman will require early warning of a stock reduction or increase policy, in order that he may plan with the Personnel Officer his labour requirements.

(c) It is recommended that a daily return of achievement is made available to all foremen, each return showing not only his own shops, but that of the factory.

(d) Higher managements should make a tour of the works at intervals; this should not be at regular times, but should take place at least once a week, and during these tours they should discuss production plans and their achievement with every foreman (see also section 9).

(e) Here lies the main purpose for which the production side of the unit exists, with the foreman as the key man of that purpose. Interest in the achievement must never be allowed to flag, and will only be fully maintained if it is kept as a personal matter between the highest management authorities and the foremen. Whilst an efficient progress department will impose a constant need for production of a particular aspect of the plan, the overall punch and drive can only come from the top, and the tempo will be set by evidence of that drive.

(f) It will help to make unreasonable demands of the foreman from time to time; the challenge of meeting such a demand being an invaluable incentive to further effort.

4. Inspection as an assistance to foremen in maintaining discipline in workmanship

(a) The Inspection Department would at first glance appear to have very little, if any, effect on discipline even in workmanship. It cannot be escaped, however, that workmanship, by

which we mean the production of an article which will perform the function for which it is designed, is very much the concern of both the Inspection Department and foreman.

(b) Discipline in workmanship is, perhaps, the most difficult of the disciplines which the foreman has to impose, as whilst drawings will set down clearly limits and dimensions, a good inspector will often pass a job which will do its work even if it is outside the limits shown, and questions on degree of finish are almost always matters of opinion.

(c) It will, therefore, be seen that if the Inspection Department are going to exercise their undoubted right to reject all work that is not to standard, and the foreman is going to exercise his right to control all the activities of his operatives, a high degree of co-operation will be required, or production of that work will soon be slowed down or even come to a standstill.

(d) This co-operation will be assisted if the foreman recognises that the Inspection Department have, in their own interests, to maintain a standard, and supports all reasonable efforts by them to enforce its maintenance. Whilst the foreman will be constantly urged for output and his natural desire will be to " force " work through Inspection, this attitude will ultimately react to his own disadvantage, in that the workmanship of his people will get slack and this will lead to slackness in other forms of discipline.

(e) It is recommended, therefore, that foremen be trained to work closely with the inspector responsible for the quality of their own shop, and that the ideal of a high degree of co-operation between inspectors and foremen be encouraged.

(f) It will be necessary from time to time for Inspection to tighten up on the general standard from all departments, and foremen must do all they can to support this. At times it may be necessary for the foreman to request a tightening himself. Records of the incidence of bad work from an individual or group should also be maintained for foremen by the Personnel Officer from waste records; thus replacing the opinion of the foreman (often used as evidence when dealing with his operators) with facts.

(g) There is a tendency amongst foremen to regard inspectors as the natural enemies of production, and it must be firmly established as a principle that the prime function of an Inspection Department is to protect both the customer and the management from bad workmanship. In this the interests of Inspection and Supervision are united.

5. Costing as an aid to good foremanship

(a) Cost returns are one of the most vital of modern management techniques, and yet in the writer's experience are the least understood. The extent to which foremen can carry a budgetary and cost responsibility is not at all impressive in British industry. This is, however, not surprising when it is remembered that many members of management do not themselves have a full understanding.

Costing techniques have improved faster than the general ability of the people for whom they supply the statistical information to understand them, and there is much room for education at foremen level on this subject.

(b) A foreman who is supplied with returns which he understands is in the position of a man running his own business, and he will react energetically to the information he receives. It is recommended that this information be supplied in chart form in support of the figures, as most foremen will not have had training in business administration and will not be used to, or familiar with, figures of this type.

(c) Period returns should be examined with the Cost Accountant and members of management so that guidance can be given in reading the returns and correcting trends, and the foremen must be taught that it is not enough to deliver on time; our survival as an industrial nation depends also on the cost being right.

(d) The effects on prices of overtime, extra labour, and night shifts are not widely understood by foremen in this country, and this part of the foreman's place in the team is often delegated to such functions as Production Engineering. It is strongly urged that foremen be trained to appreciate the advantages which will accrue from an appreciation of the cost returns, and that his objective is not merely that of making sure he is not " in the red ".

(e) The value of costing in throwing up the key factors in a production unit is also not generally understood by foremen, and the principle of discussion with Cost Accountants mentioned under (c) above in making a decision to solve almost any shop problem, even including the technical, must be implanted in supervision.

6. Definitions of responsibility between foremen and the Personnel Department for training and works discipline

(a) One of the most outstanding advances in management during the past 25 years has been the constantly increasing use of personnel control techniques. Whereas the application of personnel control was vested only in foremen and was largely by the "stick and carrot" method, it has now become an exacting and accurate science, with specialists employed full time in its deployment in most works.

Many books have been written, and the writer, in common with all who are connected with management, has heard many learned lectures on the subject.

(b) Careful analytical examination of these expoundings has revealed three main aspects of personnel work: welfare (in its purest sense excluding canteens and sports clubs for the purpose of this examination), training, and discipline. All of these had hitherto been almost the sole prerogative of foremen, except in the largest organisation, until the beginning of the Second World War, when the new power of Trades Unions, together with Governmental interest in a smooth industrial output, forced managements generally to give favourable consideration to the establishment of a Personnel Officer in their works.

(c) It is perhaps paradoxical that, whilst at first glance one would see in this movement a removal of a high proportion of the foreman's responsibility, in fact, the effect has been to increase very considerably his need for human understanding and the exercise of control of his operatives. Advances in techniques are not the sole property of managements, and foremen and the "stick and carrot" will, therefore, no longer be accepted by the operatives and their representatives. The foreman has to be aware of, and able to use, personnel control techniques, and much of his success will depend on his skill so to do.

(d) Whilst the Personnel Officer can be regarded as a specialist, his operations are very largely controlled by the amount of co-operation he can get from foremen, and his is one of the functions which the foreman co-ordinates in order to run his shop effectively. To consider in detail the three aspects mentioned:

(e) ***Welfare***

The most urgent and deserving cases of welfare need are often those who will say least about their problems. A foreman with his intimate knowledge of his people could call for welfare assistance from the Personnel Department, and will often be able to guide them in the degree of application required. This is an opportunity often seized by shop stewards, and the resulting prestige goes to them.

Foremen must be trained to accept that the well-being of their operatives, inside the limits of assistance allowed by company policy, is their responsibility, and not a service to be extracted from a reluctant management by the Trades Unions.

(f) ***Training***

Excellent training schemes are run by many authorities, including in many companies its own Personnel Department, but all these end when the trainee is at last thrust into the hurly-burly of the shop floor.

Training must by its nature be a clinical process, and the adjustment which the trainee will have to make cannot help but be difficult. A foreman who has a trainee placed in his care, has a super-sensitive human being whose understanding of what is required of him may, and probably is, coloured by his training, and whose reactions in the first few weeks will have an effect on the recovery of the money spent on training him. A foreman has also a duty to further the training of all his personnel, and he needs to be taught that to keep a man who can do a better job in one place for the sake of a quiet life, is not in the best interests of the company, or indeed the nation.

Training, like education, does not end with school-leaving, and it is on our foremen in the final analysis that we must depend to provide those who will carry the torch into the future of our industrial life. It is essential that management ensure a complete understanding in their foremen of the importance of their co-operation with those responsible for training, and their responsibility for its continuance when the trainee is on the shop floor.

(g) ***Works discipline***

Every time a foreman uses the Personnel Department to assist in maintaining discipline in his shop, he has weakened his power of maintaining it in the future. Discipline has been defined as the art of "making other people do your will believing that they do it because they want to", and this quality cannot be sub-contracted.

A foreman cannot co-operate in maintaining works discipline in his shop; it is his prerogative, and his alone. If it is necessary to take action outside a department which he controls, for example, to discharge an operator, this action must be positive, i.e. a foreman should not report a man, he should recommend

a discharge, and management must let it be clearly understood that their foreman's recommendations on matters of this type are always accepted.

It will be necessary for foremen to be completely informed on company policy in regard to works discipline, and for management to have complete confidence in their foremen to carry out this policy. Foremen should be told that management will support every decision made, and should understand that a decision on a matter of discipline cannot be taken in anger. A serious matter should always be discussed with management before being made public.

(h) Under this heading an attempt has been made to define in some detail the responsibilities between foremen and the Personnel Department. The broad principle, however, which controls their relationship is that the foremen manage their shops, and a good manager has a responsibility for his operatives' welfare, training, and discipline, which cannot be bypassed by sending the problem to the Personnel Officer. This function can advise; action is the responsibility of the foreman.

(i) There are requirements for satisfaction in employment which go beyond that of getting the " highest wage for the least work ", recently quoted by a prominent Trade Union leader as the prime objective. All of us require an incentive to work in the widest sense of the word, for there are incentives other than financial. Self-respect is a first need in the human make-up, and what man will respect himself if he feels he is not needed by his colleagues and those for whom he works ? The careful and skilled application of works discipline *at the shop floor level* by foremen who are in constant touch, and who are themselves measured by their own workpeople, will do much to ensure a feeling of being needed in each of these workpeople. Foremen who " bully " will certainly, provided they are strong enough, give an outward appearance of maintaining works discipline.

Foremen who *lead*, and whose shop discipline is based on a recognition of the "rights of man ", will have a team of operatives whose own enjoyment of their efforts in the company's productivity effort will do much to enhance its chances of success.

7. Foremen and the Trades Unions

(a) Trades Unions and employees have procedure agreements which clearly lay down the line to be followed if a grievance or difference is raised by an operative. It should be regarded as axiomatic by management that supervision will assume responsibility for everyday labour relations in its own sphere, and only if no understanding can be reached at first level should the way be clear for the Union to discuss the issue with top management. Management generally fail in this simple approach, and in this failure reduce the value of the people they employ to supervise beyond measurement.

(b) There does not seem to be an awareness of the unsatisfactory situation which arises when information and decisions reach the operatives through a leakage, or worse, through a shop steward. The aim must be to keep foremen ahead of the Trade Union representatives in their knowledge of what is going on.

(c) The advent of power unions has made the temptation of direct consultation almost irresistible to many managements and, indeed, there is much to be said for it. It must be remembered, however, that the foreman is first-line management on *the shop floor* and cannot divorce his daily routine from the workpeople, as the top management can. Therefore, if he is to count in the eyes of his people he must be knowledgeable. There is no reason why it should be believed that the foremen have less interest in the future of the company than the shop stewards and operatives, and yet on so many issues the foreman only finds future policy by discussion with his own operatives.

(d) Whilst managements can and do make use of shop stewards to get in touch with employees, there can be no substitute for foremen as first-line management, interpreting to the shop floor management decisions.

(e) Foremen being individuals, as opposed to the mass presented by organised labour, are often found to have a very small voice in matters of common interest (even such matters as the date of the annual holiday) and management have a definite responsibility towards their supervision in seeing that their views are not only expressed, but are regarded as those of senior members of the organisation.

(f) It is agreed that the extension of supervisor unions on a wide scale would be a retrograde step in our industrial history, but it will surely come unless managements remove, by treating the foreman as part of the management, the vacuum into which they are being forced by the growth of Employer Associations on the one hand, and Trades Unions on the other. The age of the independent in industry has passed, and collective action has taken its place. Into which block of collective action the foreman will go depends entirely on the readiness of managements to incorporate foremen into its structure.

(g) It is to be desired that foremen be encouraged to form within the works a Foremen's Association, which can have both a social and political background. Social, because a foreman's life can be very lonely, and particularly in a small community, this loneliness can be shared by his wife, and political because whilst no sort of collective bargaining can be allowed, the expression of the foreman's viewpoint can have little weight unless co-ordinated. Management will need tact and care in fostering such an association, but if well run it will do much to enhance the value of the foreman as a member of a team, and will serve as an incentive towards gaining foreman status.

8. Training future foremen

(a) Training can only succeed selection and it is the selection of future foremen which presents the larger problem. It is assumed that correct selection will allow training to be given to improve a man's potential. The danger is that frustration will set in if the man is selected and trained, without a definite appointment being available at the end of the course.

(b) One method is to advertise within the works and run a course on foremanship, making it clear that selection for a course in no way implies a future appointment.

Whilst this has a value in enabling management to observe the ability of potential foremen in classroom conditions, it is not considered by the writer to justify the danger of producing disgruntled and frustrated men, who have a bad effect on general morale.

(c) The foregoing being accepted it becomes clear that a " future foreman " is one who has been appointed, but who has not yet taken up his new duty. Objections will be raised to the time factor involved (often filling a vacancy is urgent). It is commonly the practice of managements to promote from the shop floor at the last moment, giving little thought to the ability of the appointee beyond saying " he is the fastest man on the section ", or " he has been with the company longest ", only to find that they have over the years acquired a supervisor whom they are unable to take fully into the management team, because he has no idea of what is required of a managerial approach to running a department.

(d) The form of training will vary according to the needs of the company, the foreman, and the department he is to run, but certain requirements as general principles can be set down. These are :-

1. training in human relations;
2. company policy and objectives;
3. business administration;
4. Factories Acts;
5. Trade Union local and national agreements;
6. budgetary and cost control;
7. wages and bonus calculations;
8. operator training;
9. communications, enquiries, clear report writing, and verbal instructions.

(e) It is to be recommended that all of this first training should be carried out within the organisation. Supervisor training becomes, therefore, a tool of management within the normal operation of the company, and the executives who will be concerned will each be known to and will know the new foremen. Outside specialist courses can be used at a later stage, but will only serve to confuse a man who is not yet used to taking those things which fit his own organisation's requirements and disposing of the rest.

(f) It will be noted that technical skill and job " know-how " have not been mentioned among the principles laid down. It has been stated in section 2 of this thesis that this is the age of the specialist and the foreman will be required to fulfil the wide rôle of foremanship.

Whilst a man of good mental ability and education can quickly acquire the necessary " know-how " for all but the most exceptional requirements of craftsmanship, it is by no means certain that the craftsman will ever acquire the personality, perseverance, initiative and integrity which modern foremanship demands.

(g) Most of this training can be carried out by sessions of a maximum of two hours' duration during works time. It will, of course, be individual and run concurrently with the man getting to know the department he is to control.

Where promotion is inside a department in which he has latterly been working as an operative, it is suggested that a complete break of two or more weeks be made, in order to point the difference in status to his late colleagues.

(h) Training for foremanship should be progressive, and after the introductory period of training the new foreman should be inducted into training schemes being run for existing foremen, and encouraged to take part in discussions run by the Foremen's Association and/or Works Manager (see sections 3 and 7).

9. The personal approach by the Works Manager stimulating the co-operation of supervision with management

(a) The Works Manager leads a team which, like any team in any field of endeavour, has a target. It therefore becomes at once evident

that the team must, with the leader, know exactly what the target is. The team as a whole must obey certain rules and each member must know clearly where his position is and what his contribution will do towards the common objective.

How then can a Works Manager, beset as he is with all the day-to-day routine and problems of his office, set out to form and lead his team ?

(b) Suggestions have been made in this thesis as to some of the many techniques which are available and which can be used, but all these will fail if the leader is never seen. The Works Manager *must* be seen on the shop floor at least once a day and he should make a firm point of talking to every foreman at least once a week. This talk may be of complaint or praise, it may be concerned with the work of the factory, or it might even be about the foreman's children; the important thing is that in the eyes of the Works Manager the foreman exists, and in the heart of the foreman he knows that he matters.

(c) The attendance of the Works Manager and his lady at foremen's socials, works dinners, and the like, is of equal importance and every care must be taken to meet the foreman and his lady on a personal basis.

Respect for the Works Manager will exist by virtue of his office; in his foremen he must deepen this respect into admiration, and even affection, and this can only be done by personal contact.

Foremen should know that the Works Manager has a very real interest in them as individuals, and he must be available at very short notice to see any foreman who wishes to discuss personal problems with him.

(d) Co-operation between supervision and management, where supervision is part of the management, will be automatically ensured, and a supervision which is selected and trained, well-informed and supported, and which is confident in its own ability, will amply repay the effort which will be required to create it.

(e) We are facing a future where an independent labour force organised into powerful Trades Unions, is no longer content to be told what should be done, but also ask why. Understanding and evaluation of the human factors has created a need for "leaders" in supervision, and these leaders will only be thrown up if management are prepared to provide supervision who are confident, trained, have authority and are supported, who have prospects of promotion and whose salary level is above that of the people they control.

The impact of modern management techniques has created a need for foremen of wider views and capable of accepting responsibility over wider fields. British industry must foster the challenge of finding and training these men quickly, if it is to replace the race of foremen who have now become redundant because of these changes.

Conclusion

The qualities of leadership required from foremen would (if ever they existed in one man), mean he would not be available for the post; he would be required elsewhere as a Managing Director. In pointing to the ideal, the writer has been very conscious of the impossibility of achieving it at foreman level. What is important is that in line with technical advances, and changes in the management structure, a recognition of the effect of such changes on these key men is ever present. It is clear that foremen can no longer be regarded as part of a purely formal hierarchy; we are concerned today with foremen who produce results in terms of industrial efficiency, and also in terms of the human happiness of those who work under them. The Job Relations Course in Training within Industry which teaches that "good supervision means that the supervisor gets the people in his department to do what he wants done, when it should be done, and the way he wants it done, because they want to do it", sums up perfectly the place of the foreman in management today.

In conclusion it is considered that the creation of a new type of foreman, confident in his place in management and in his ability to create and lead his own team, is a vital necessity in every productive organisation, and the provision of this man will do much to maintain the country's position as one of the foremost industrial nations of the world.

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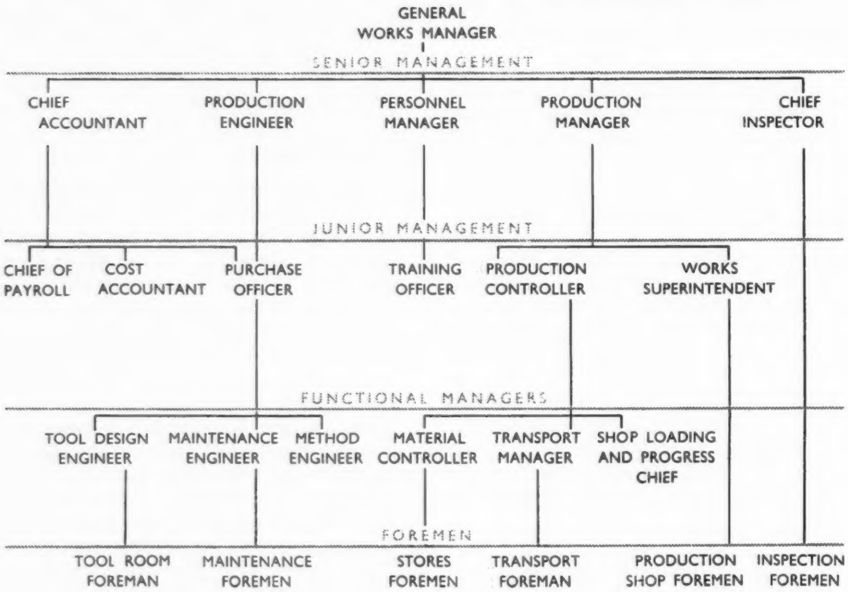
(For Appendices, please see overleaf.)

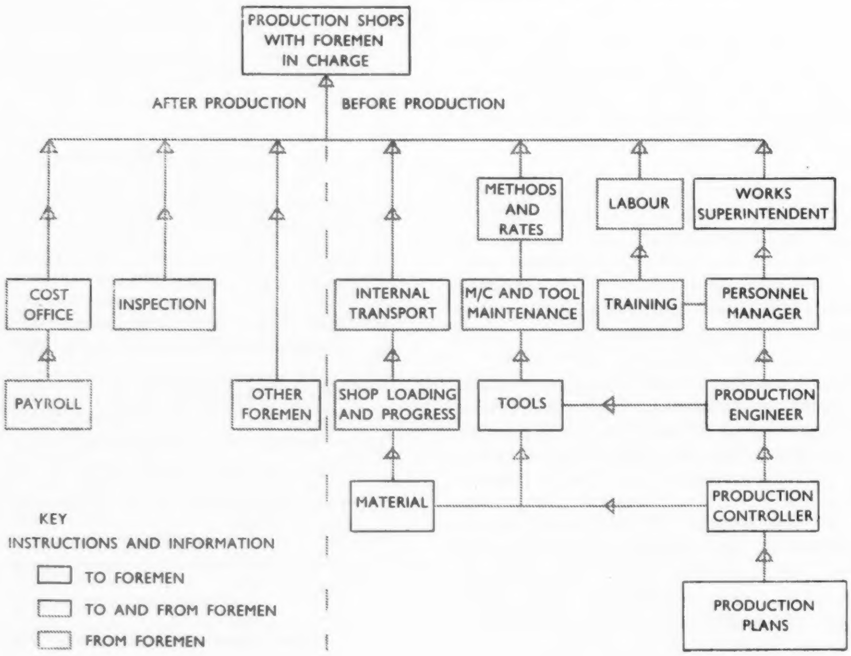
APPENDIX I.

CHART TO SHOW RELATIONSHIP BETWEEN FOREMAN AND MANAGEMENT IN TYPICAL MEDIUM PRODUCTION UNIT



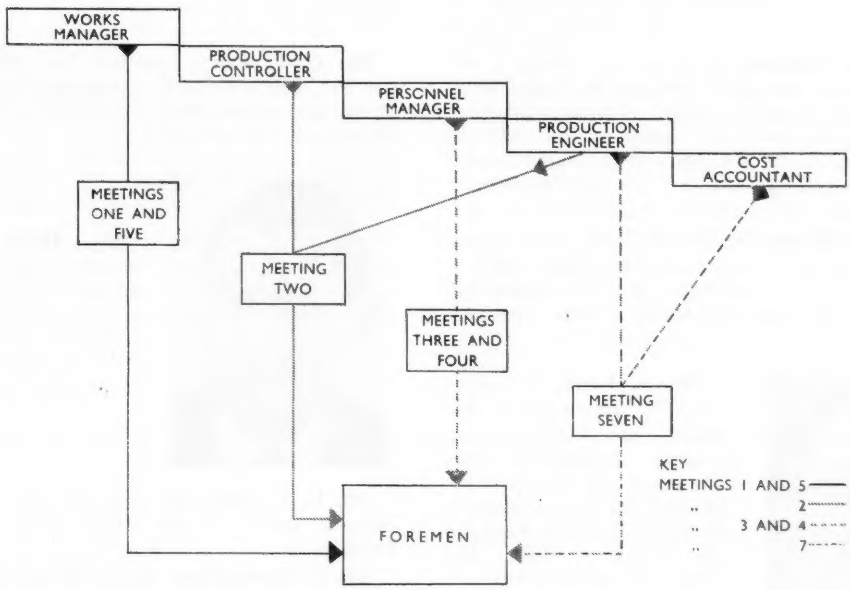
APPENDIX 2

CHART TO SHOW CO-ORDINATION OF FUNCTIONS BY FOREMEN ON "SHOP FLOOR"



APPENDIX 3

CHART TO SHOW REGULAR COMMUNICATIONS WITH MANAGEMENT SET UP BY THE MEETINGS DETAILED IN SECTION 2 PARA G.



NOTE: MEETING 6 NOT SHOWN. ATTENDANCE AT THIS WILL BE AS REQUIRED

GROUP PROVIDENT SCHEME

THE Institution has a Provident Scheme for its members. The object is to safeguard members against the expense of private treatment for major illnesses, including surgical operations. Private treatment in nursing homes, hospital pay-beds and private specialists' consulting fees, do not come under the National Health Service, and the patient has to pay the full cost. The Provident Scheme is designed to enable members of the Institution, and their dependents, to make the best and speediest arrangements without having to worry about the cost, and to provide a measure of privacy during treatment which is not possible under the National Health Service. Thus the Scheme is not intended to displace the National Health Service, but to provide supplementary benefits.

Under the Institution's Group Provident Scheme, the British United Provident Association's standard rates of subscriptions are reduced by 20% and arrangements are made for the collection of subscriptions annually by Banker's Order made payable to the Institution. Members are entitled to benefit immediately on acceptance and are not subject to the usual three months waiting period.

If you are already a private member of the B.U.P.A. and under 65 years of age, you can apply to transfer to the Institution's Group Scheme and get the benefit of 20% reduction in fees. A refund of any balance of your current individual subscription which may be outstanding, would be made.

Members interested in joining this Group Scheme are asked to write to the Secretary of the Institution, asking for full details and an application form.

It should be noted that this Scheme does not apply to members outside the United Kingdom.

news of members

Mr. A. E. Clifford, Member, has resigned his appointment as Assistant General Manager with David Brown Industries Ltd., Tractor Division, Meltham, Huddersfield, in order to join Messrs. Crittall-Luxfer Ltd., Nottingham, as Director and General Manager. Mr. Clifford is a past Member of Council.

Mr. H. W. Harper, M.B.E., Member, who joined the firm of Tweedales & Smalley Ltd., Castleton, last December as General Manager and was appointed a Director in February last, has now been appointed Managing Director.

Mr. F. Limb, Member, has been appointed to the Board of Directors of Ericsson Telephones Ltd. Mr. Limb, who is appointed Works Director, commenced his career with the General Post Office in 1913. He joined Ericssons in 1925 as Chief Circuit Engineer. In 1957, Mr. Limb received the Insignia Award in Technology of the City and Guilds of London Institute.

Mr. S. A. J. Parsons, Member, has been appointed Principal of the Liverpool City College of Technology. Mr. Parsons is a past Chairman of the Membership Committee.

Mr. A. J. Perkins, O.B.E., Member, has recently retired from the Ministry of Supply, and he will take up duties as part-time Consultant with the Atomic Energy Authorities, in the near future.

Mr. H. C. Perry, Member, has relinquished the position of Production Engineer with The Plessey Co., Ilford, and is now Works/Production Manager with Modern Techniques Ltd.

Mr. Denis S. Player, Member, has recently been elected deputy to Mr. Sydney Player, Chairman of The Newall Engineering Co. Ltd., Peterborough, and its subsidiaries.

Mr. L. V. Store, Member, has been appointed as Superintendent of the Royal Ordnance Factory, Cardiff.

Mr. C. Taylor-Cook, Member, has been appointed Principal of Westminster Technical College.

Mr. C. L. Taylor, Member, has relinquished his position as Chief Production Engineer with Blackburn & General Aircraft Ltd., Brough, and has taken up an appointment as Commercial Manager with J. S. Chinn & Co. Ltd., Coventry.

Mr. T. B. Brook, Associate Member, has taken up an appointment as General Manager (Production) with Black & White (Accrington) Ltd.

Mr. D. J. Curtis, Associate Member, has recently taken up a position as Instructor for Workshop Technology and ancillary subjects at Taunton Technical College.

NEWCASTLE UPON TYNE DINNER-DANCE

This photograph, taken at the Newcastle upon Tyne Section Dinner-Dance held on Friday, 28th February last, shows (from left to right) Mr. J. E. Hill, Vice-President of the Institution; Mrs. C. B. Abbey; The Lady Mayoress; The Lord Mayor of Newcastle upon Tyne, Alderman J. W. Telford; and the Section Chairman, Mr. C. B. Abbey.

Lt.-Col. C. J. Doyle, O.B.E., Associate Member, has now retired from the Army and is taking up an appointment at The British Transport Commission, Work Study Training Centre, Watford.

Mr. R. E. Gates, Associate Member, has now taken up an appointment with Ronald Trist & Co. Ltd., Slough, Bucks.

Mr. E. H. Goldsmith, Associate Member, has relinquished his appointment as Lecturer at Hatfield Technical College and has taken up an appointment as Senior Lecturer in Management and Production Engineering in the Department of Engineering at Reading Technical College.

Mr. W. T. Neill, M.B.E., Associate Member, who is at present Deputy General Manager of de Havilland Propellers Ltd., Lostock, has been appointed Director and General Manager of Platt Brothers & Co. Ltd., Hartford Works, Oldham.

Mr. W. R. Page, Associate Member, is now Works Manager of the Woods Fan Division of Amalgamated Electric Corporation Ltd., Toronto.

Mr. P. S. Agarwal, Graduate, has been appointed as a Service Engineer, with British Timken Ltd., New Delhi, India.

Mr. M. B. Blunn, Graduate, has recently taken up a position of Development Engineer with K.S.M. Products Incorporated, New Jersey, U.S.A.

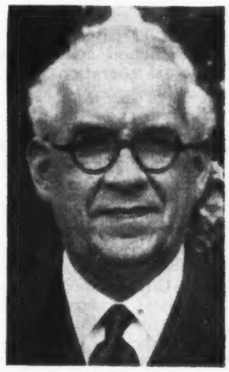
MATERIALS HANDLING GROUP NEW REPRESENTATIVE

The Derby Section of the Institution have nominated Mr. D. H. Goss, A.M.I.Prod.E., 11 Inglesby Avenue, Derby, as their representative on the Materials Handling Group.

Obituary

Mr. G. A. FIRKINS, M.I.Prod.E.

An appreciation by the Wolverhampton Section.



THE sudden passing of Mr. George Arthur Firkins, during his second year of office as Chairman of the Wolverhampton Section, was recorded with the deepest sorrow and regret. Mr. Firkins, who was 56 years of age, represented with distinction the successful engineer of his generation, and his achievements were founded on personal enterprise and initiative, coupled with hard work and a wide diversity of experience.

At the age of 14, he began his engineering career as an apprentice with G. A. Weir, Ltd., of Glasgow, and at the time of his death he was Managing Director of G. A. Firkins, Ltd., of Wolverhampton, the Company which he established some 10 years ago. One of the highlights of his career was the important part he played in the aircraft industry during the Second World War; he also spent some time in South America.

Throughout his life, he displayed to the full a willingness to venture and to meet any challenge with which he was faced; in a world in which specialisation is ever-increasing, his kind is becoming fewer with the passing years, and the engineering profession will undoubtedly feel their loss.

Mr. Firkins joined the Wolverhampton Section at the end of 1954, and succeeded to the office of Chairman in 1956. During his membership he worked enthusiastically and untiringly for the Institution, and his activities included service on the Regional Committee, and on the Membership Committee, of which he was Vice-Chairman.

Those of us who have had the pleasure of serving and working with him will remember him most for his personal charm, his friendship and in particular for the deep sincerity which impressed all those who came into association with him.

The Wolverhampton Section are proud to honour his memory.

Hazleton Memorial Library

ADDITIONS

Armstrong, W. H. **"Machine Tools for Metal Cutting."** *New York, London, etc., McGraw-Hill,* 1957. 345 *pages. Illustrated.* 39s.

The book is based on lectures given at the Machine Tool Laboratory Classes at the Pennsylvania State University. Chapter 1 defines, analyses and classifies machine tools; Chapter 2 describes the principles and tools employed in metal cutting; Chapter 3, the various classes of fit uses in machine construction; and Chapter 4, the metal cutting process, and the tools, tool materials, cutting speeds, and fluids used in machine tool operation. Other chapters describe specific metal cutting tools and processes, screw thread production and gear production, semi-automatic and automatic machines, electro-spark machining, ultrasonic machining and chemical milling. The treatment is elementary.

Bell, William D. **"A Management Guide to Electronic Computers."** *New York, London, etc., McGraw-Hill,* 1957. 403 *pages. Illustrated. Diagrams.* 50s. 6d.

The first part of the book describes, in non-technical language, what an electronic computer or electronic data processing machine is, and what it can do, with specific examples. This is followed by chapters on programming and on possible future uses of computers. The chapter on "Management Questions and Answers" attempts to answer the questions: "Are electronic computers ready for business applications?"; "What about obsolescence?"; "Should we buy or rent?"; "How large must the organisation be?"; "Should we acquire one large or two smaller systems?"; "What about maintenance?"; "How do you select and install a system?". The book concludes with 11 case studies of computer applications including production control, accounting, air traffic control, and actual operations.

Blainpain, Edouard. **"Téorie et Pratique des Outils de Coupe."** *Paris, Editions, Eyrolles,* 1955. 642 *pages. Illustrated. Diagrams.* 1,057 francs.

The theory and practice of cutting tools. Contents: Cutting action — The geometry of the tool — Tool materials — Tool tips — Chip formation — Machinability — Tool Wear — Cutting angles — Chip breakers — Cutting tool efficiency — Turning and screw cutting tools — Planing and slotting tools — Boring and drilling tools — Milling cutters — Taps, dies and chasers — Scrapers — Broaching tools — Cutting fluids — Tool sharpening — Recommendations for tool maintenance.

Brech, E. F. L. **"Organisation: The Framework of Management."** *London, etc., Longmans Green,* 1957. 424 *pages. Tables.* 45s.

"This book has a simple and single aim — to make available for the practising Director and Manager, a simple explanation of the nature of organisation structure and of its role within the practical application of the process of management." Part 2 of the book is a description of the practical application of the principles of organisation propounded in Part 1. The nature of responsibility, the various kinds of responsibility, the practical definition of responsibility, and the principles of delegation are discussed and illustrated by schedules of the organisation of a company operating five factories. The responsibilities of top management are similarly discussed and illustrated. The chapter on centralisation v decentralisation includes a discussion of the terms "delegation" and "decentralisation". There is a chapter on the function and responsibilities of various kinds of committees, and on government by committee. The appendices comprise an outline history of thought on organisation, and notes on the Fleck Report on the organisation of the National Coal Board, and on the Herbert Report on the organisation of the electricity supply industry.

Donaldson, Cyril, and LeCain, George H. **"Tool Design."** 2nd edition. *New York, London, etc., McGraw-Hill,* 1957. 557 *pages. Illustrated. Diagrams.* 52s.

The book was written at the Rochester Institute of Technology (Rochester, New York), and is arranged primarily for a course having lecture-discussion periods with laboratory drawing time assigned. There are questions and problems, and a list of references at the end of each chapter, as well as many problems fully worked out as examples. Contents: Tool drafting — Manufacturing processes as they affect the designer — Properties of materials — Tolerances and allowances — Springs — Welding — Cutting tools — Punch and die design — Gauges and gauge design — Elementary jigs and fixtures — Details of jigs and fixtures — Practical design of jigs and fixtures — Construction of Brown and Sharpe Automatic Screw Machine — Tools used on Brown and Sharpe Automatic Screw Machine — Cam Design — Turret-lathe tooling.

Goode, Harry H., and Machol, Robert E. **"System Engineering: An Introduction to the Design of Large Scale Systems."** *New York, London, etc., McGraw-Hill,* 1957. 551 *pages. Illustrated. Diagrams.* 77s. 6d.

This book attempts to show how a number of subjects such as statistics, computers, Games theory, information theory, servomechanisms and control are co-ordinated by systems engineers to attack large scale problems in engineering, such as the development of guided missiles, telephone systems, or guided missiles systems. It attempts "to provide for the engineer who is, or aspires to be a member of a system design team sufficient technical background to aid him in his job" and to present "methods in system design; place in its proper and relative position each of the new sciences which have become handmaidens to system design; present the central problem, functions, and languages of these sciences; and furnish some practical information on the functioning of a system design team". Although the book is largely mathematical in its content, most of it can be understood by those with a knowledge of elementary calculus.

Institute of Metals, London. **"The Final Forming and Shaping of Wrought Non-ferrous Metals."** A symposium held in London on the occasion of the Annual General Meeting of the Institute, 12th April, 1956. *London, the Institute,* 1956. 128 *pages. Illustrated. Diagrams.* 21s.

(Institute of Metals, Monograph and Report Series No. 20.)

Contents: Galloway, D. F. — The machining properties of non-ferrous metals; Grainger, John A. — The deep drawing and spinning of sheet metal, with particular reference to non-ferrous metals; Fielding, J. — Rubber pressing; Johnson, W. — Research into some metal-forming and shaping operations; Griffin, E. — Cold

roll-forming and manipulation of light-gauge sections; Edwards, R. D. — Stretch-forming of non-ferrous metals; Perry, T. G. — Bending and allied forming operations; Wilkinson, R. G. — The hot forming of magnesium alloys; General discussion.

Larke, Eustace C. "**The Rolling of Strip, Sheet and Plate.**" *London, Chapman and Hall,* 1957. 404 *pages. Illustrated. Diagrams.* 63s.

Contents: Modern rolling plant — Multi-tool mills — The design, use and reproduction of roll cambers — Magnitude, causes and control of thickness variation along the length of rolled strip — Factors which determine the magnitude of the rolling load — Calculation of cold-rolling loads and rational rolling schedules — The influence of coiler and decoiler tension on the rolling load — The meaning and significance of rate of deformation — Resistance to deformation during hot rolling — Calculation of hot rolling loads — The energy consumed and horsepower developed during cold-rolling — The energy consumed and horsepower developed during hot-rolling — Productive capacity of strip mills.

Lasser, J. K. (editor). "**Business Management Notebook.**" Revised edition. *New York, London, etc., McGraw-Hill,* 1954. 809 *pages.* 66s.

Contents: How to find the right form for your business — How to finance your business — How to organise your business for more efficient management — How to avoid the risks in business — How to buy and sell a business — How to market your products — How to organise good customer relations — How to organise good employee relations — How to ensure better relations with stockholders — How to find the best location for your business — How to run an accounting system — How to control your distribution costs — How to run a cost system — How to avoid business fraud — How to use budgets to control a business — How to design systems for internal control of a business — How to control business paper work — How to buy business insurance — How to do business abroad.

Operational Research Society, London. "**Proceedings of the First International Conference on Operational Research (Oxford, 1957).**" Organised by the Operational Research Society, United Kingdom; the Operations Research Society of America; and The Institute of Management Sciences. *London, English Universities Press for the Conference Committee,* 1957. 526 *pages. Diagrams.* 50s.

The 28 Papers presented and discussed are in three groups:-

1. Papers on the functions and philosophy of operational research.
2. Papers on the methodology of operational research, including Papers on telephone traffic (Holland), machine interference (Israel), the simulation of chance events (U.K.), and water storage policy in a simplified hydroelectric system (U.S.A.).
3. Papers on the applications of operational research, including Papers on the transport of coal to power stations (U.K.), marketing locations (U.S.A.), and quarrying and mining problems (Canada).

The Proceedings also contain accounts of the state of operational research in the 16 countries represented at the Conference.

THE 1960 ASSOCIATE MEMBERSHIP EXAMINATION

Specimen Examination Papers for the 1960 Associate Membership Examination are now available from the Publications Department, The Institution of Production Engineers, 10 Chesterfield Street, London, W.1, price 3s. 6d. per set (plus 6d. to cover postage and packing).

RESEARCH PUBLICATIONS

The Institution is advised by PERA that Dr. G. Schlesinger's book on "Accuracy in Machine Tools: How to Measure and Maintain It" is now out of print and cannot, therefore, be supplied. The following I.Prod.E. publication is, however, still obtainable from PERA at "Staveley Lodge", Melton Mowbray, Leicestershire.

"Practical Drilling Tests" by D. F. Galloway and I. S. Morton. Price 21s.

DIARY FOR 1958

12th - 21st May	**Production Conference and Exhibition,** Olympia — **"Production Fights Inflation".**
21st May	**Fourth Conference of Engineers** and those responsible for Standards matters in Industry, London.
27th - 31st August ...	**Annual Summer School,** Ashorne Hill, Warwickshire. (See Supplement to this Journal.)
13th 14th 15th October	**Materials Handling Convention,** Brighton.
29th October	**Annual Dinner of the Institution,** Dorchester Hotel, London.
11th December	**The 1958 Sir Alfred Herbert Paper,** to be presented at the Royal Institution, London. Speaker: **Sir Cecil Weir,** Past President of the Institution. Subject: **"The European Common Market — Its Origins and Implications".**

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1957/58

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S. Downie ... *Sydney*
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Melbourne Graduate (Victoria Australia)	H. B. Davies, 77 Longview Road, North Balwyn, Victoria, Australia.
Sydney (New South Wales) ...	K. G. Slorach, 34 Anderson Avenue, Ryde, New South Wales, Australia.

CANADA

Canada	Frank R. Taylor, 1 Cheritan Avenue, Apt. 110, Toronto 12, Ontario, Canada.

INDIA

Bombay	C. R. Pal, The Crescent Iron & Steel Works Ltd., Goregaon (East), Bombay, S.D., India.
Calcutta	S. R. Chatterjee, Machinery Manufacturing Corporation Ltd., P.61 Circular Garden Reach Road, Kidderpore, Calcutta, India.

NEW ZEALAND

New Zealand	G. Stedman, 3 Harrison Avenue, Belmont, Takapuna, Auckland, New Zealand.

SOUTH AFRICA

South Africa	A. Aitken, 209/211 Pharmacy House, 80 Jorissen Street, Johannesburg, P.O. Box 10837, South Africa.

UNITED KINGDOM

Birmingham	H. W. White, "Spring Pools", 677 Birmingham Road, Lydiate Ash, Bromsgrove, Worcs.
Cardiff	C. L. Griffiths, "Brynteg", 139 Tyntyla Road, Llwynypia, Rhondda, Glamorgan.
Cornwall	F. G. Hawke, 3 Bellevue Terrace, East Hill, Tuckingmill, Camborne, Cornwall.
Coventry	A. S. Hopkins, 39 Oaks Road, Kenilworth, Warwicks.
Derby	P. Warburton, 16 Vicarage Road, Chellaston, Derby.
Doncaster	G. R. Wimpenny, 16 Tickhill Square, Denaby Main, Doncaster.
Dundee	J. Nicolson Low, Technical College, Bell Street, Dundee.
Edinburgh	A. S. Wilson, Ferranti Ltd. (Laboratory Workshop), Ferry Row, Edinburgh, 5.
Glasgow	W. H. Marley, G. & J. Weir Ltd., Cathcart, Glasgow, S.4.
Gloucester	B. E. Gwynne Clarke, "Chez-Nous", Okus Road, Charlton Kings, Cheltenham.
Halifax & Huddersfield ...	C. W. Overin, 353 Whitehall Road, Westfield, Wyke, near Bradford, Yorks.
Ipswich & Colchester ...	H. F. Harker, Ransomes, Sims & Jefferies Ltd., Orwell Works, Ipswich.
Leeds	J. L. Townend, 26 Moor Allerton Drive, Street Lane, Leeds, 17.
Leicester & District	E. G. Davis, 19 Festival Avenue, Humberstone Lane, Thurmaston, Leics.
Lincoln	H. W. Wright, 101 Longdales Road, Lincoln.
Liverpool	(Acting) H. Mason, 51 Stairhaven Road, Liverpool, 19.
London	R. J. C. Whitaker, The Glacier Metal Co. Ltd., Ealing Road, Alperton, Middx.
Luton	J. F. W. Galyer, Engineering Department, Luton & South Bedfordshire College of Further Education, Park Square, Luton, Beds.
Manchester	J. P. Speakman, 223 Douglas Road, Atherton, near Manchester.
Newcastle upon Tyne ...	A. C. Foskew, 35 Oakwood Avenue, Low Fell, Gateshead, 9.
Northern Ireland	J. G. Easterbrook, "Hilleen", 22 Ascot Park, Knock, Belfast.
Norwich	J. I. Hilder, 2a Gorse Road, Thorpe, Norwich.
Nottingham	C. N. T. Manfull, Chellaston House, Thurgarton Street, Nottingham.
Oxford	F. S. Chappell, 58 Lancut Road, Witney, Oxfordshire.
Peterborough	N. Holmes, "Arncliffe", 11 Mary Armyn Road, Orton Longueville, Peterborough.
Preston	W. H. Preston, 25 Clifton Avenue, Leyland, Lancashire.
Reading	R. W. H. Mark, "The Beeches", 41 Reading Road, Woodley, Berkshire.
Rochester & District ...	W. G. Clements, 11 Charing Road, Gillingham. Kent.
Sheffield	T. F. Newton, c/o E. Pryor & Son Ltd., West End Works, Broom Street, Sheffield, 10
Shrewsbury	W. M. Buchan, Llanberis, 36 Mytton Oak Road, Shrewsbury.
Southampton	J. W. Taylor, 44 Deacon Road, Bitterne, Southampton.
South Essex	F. Hopkinson, "Woodley", 40 Highfield Road, Chelmsford, Essex.
Swansea	C. L. Clarke, 11 Alder Road, Cimla, Neath, South Wales.
Stoke-on-Trent	W. R. Bailey, "Rivelyn", 2 Crossfield Avenue, Knypersley, Biddulph, Stoke-on-Trent.
Tees-Side	J. H. Cooper, 48 Hob Hill Close, Saltburn-by-the-Sea, Yorks.
Western	A. Eustace, 19 Ferndale Road, Northville, Bristol, 7.
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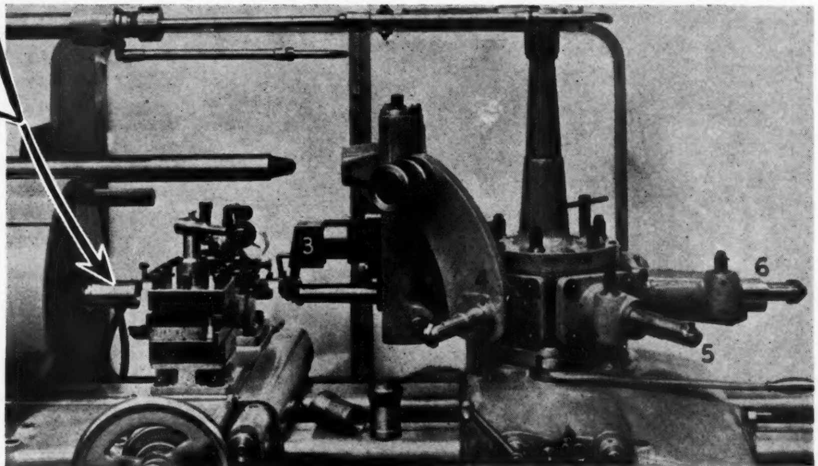

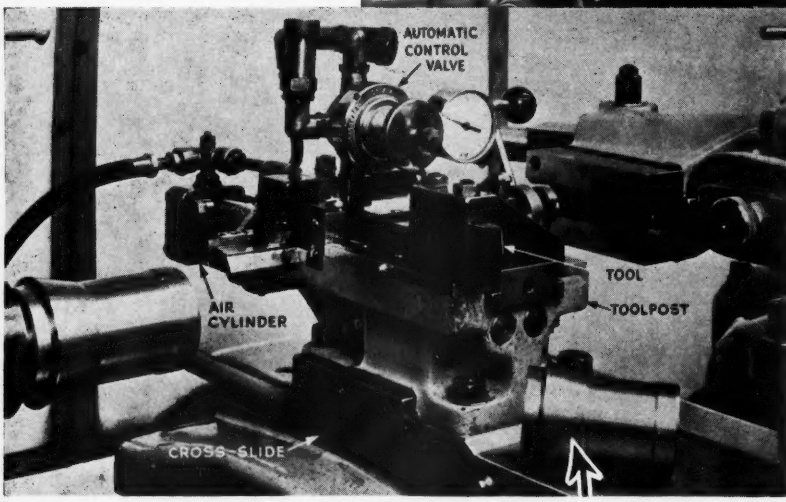

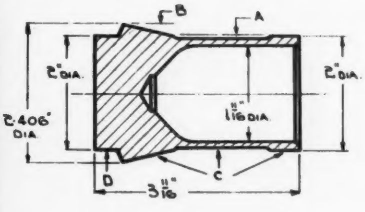

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	Hex. Turret	Cross-slide			
1. Feed to Stop and Start Drill	1	—	350	—	Hand
2. Support and Rough Form Taper	2	Front 1	100	66	Hand
Rough Form Head	—	Front 2	100	66	Hand
Drill and Rough Knee Turn 2" dia.	3	—	200	161	266
4. Finish Turn and Face D	—	Front 3	700	440	Hand
5. Profile Turn C (Copy Attachment)	6	Rear	700	440	186
6. Rough Bore Bottom	4	—	170	75	Hand
7. Microbore $1\frac{11}{16}$" dia.	5	—	1000	442	266
8. Finish Bore Bottom, Face and Chamfer	6	—	70	30	Hand
9. Part Off	—	Front 4	240	126	Hand

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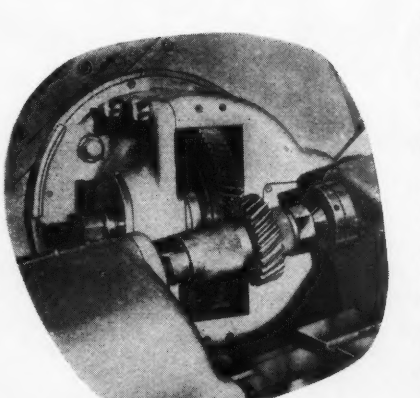

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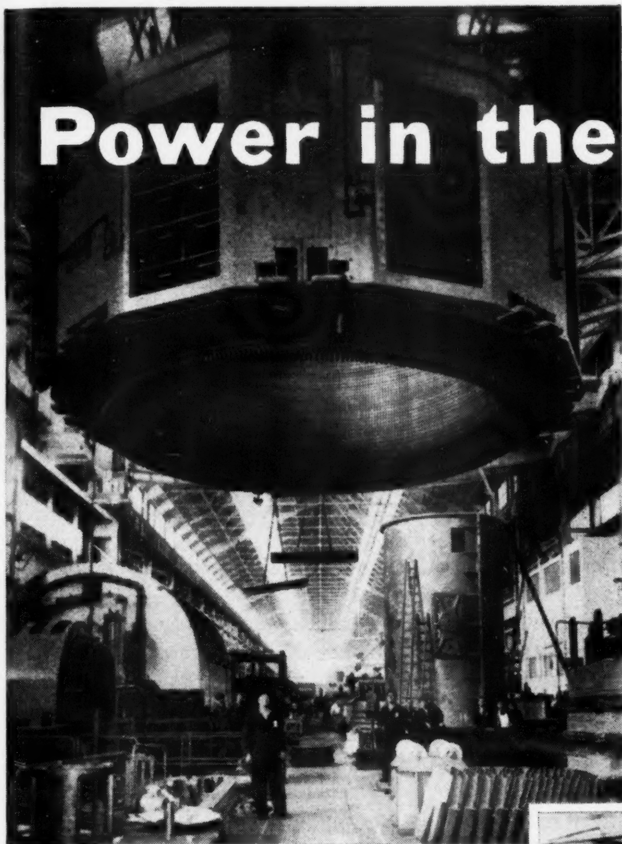

Stator of the 75,000 kVA 214 r.p.m. vertical generator. One of four ordered for the station.

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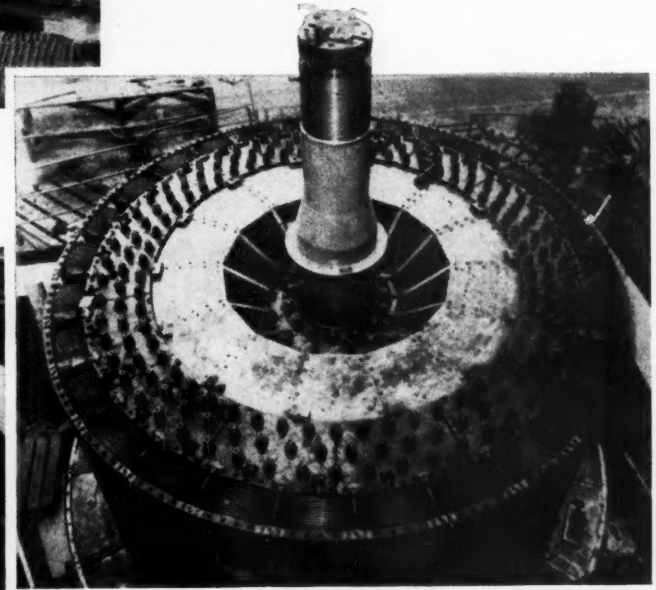
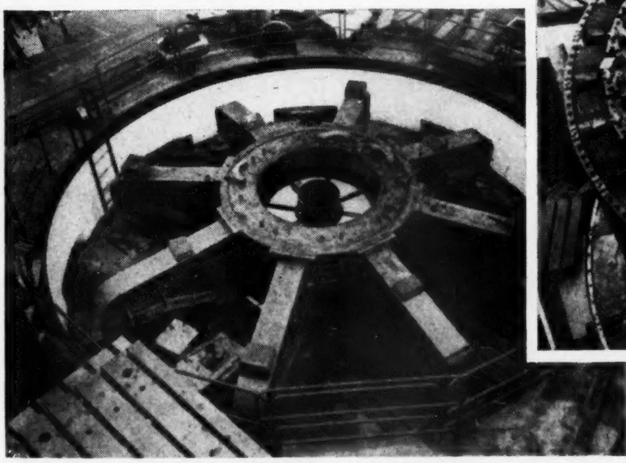


The rotor of the 75,000 kVA vertical generator.



Assembly of thrust bearing bracket

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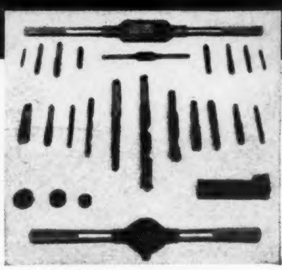

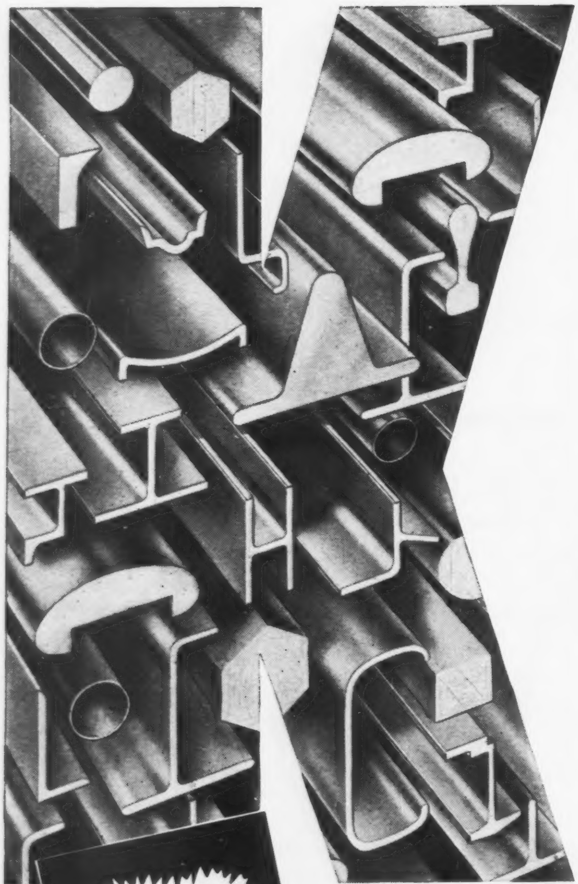

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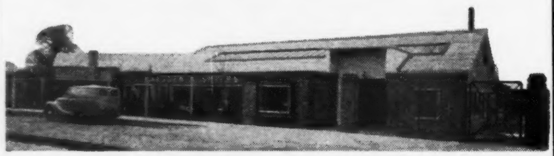

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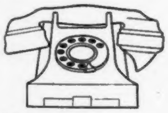

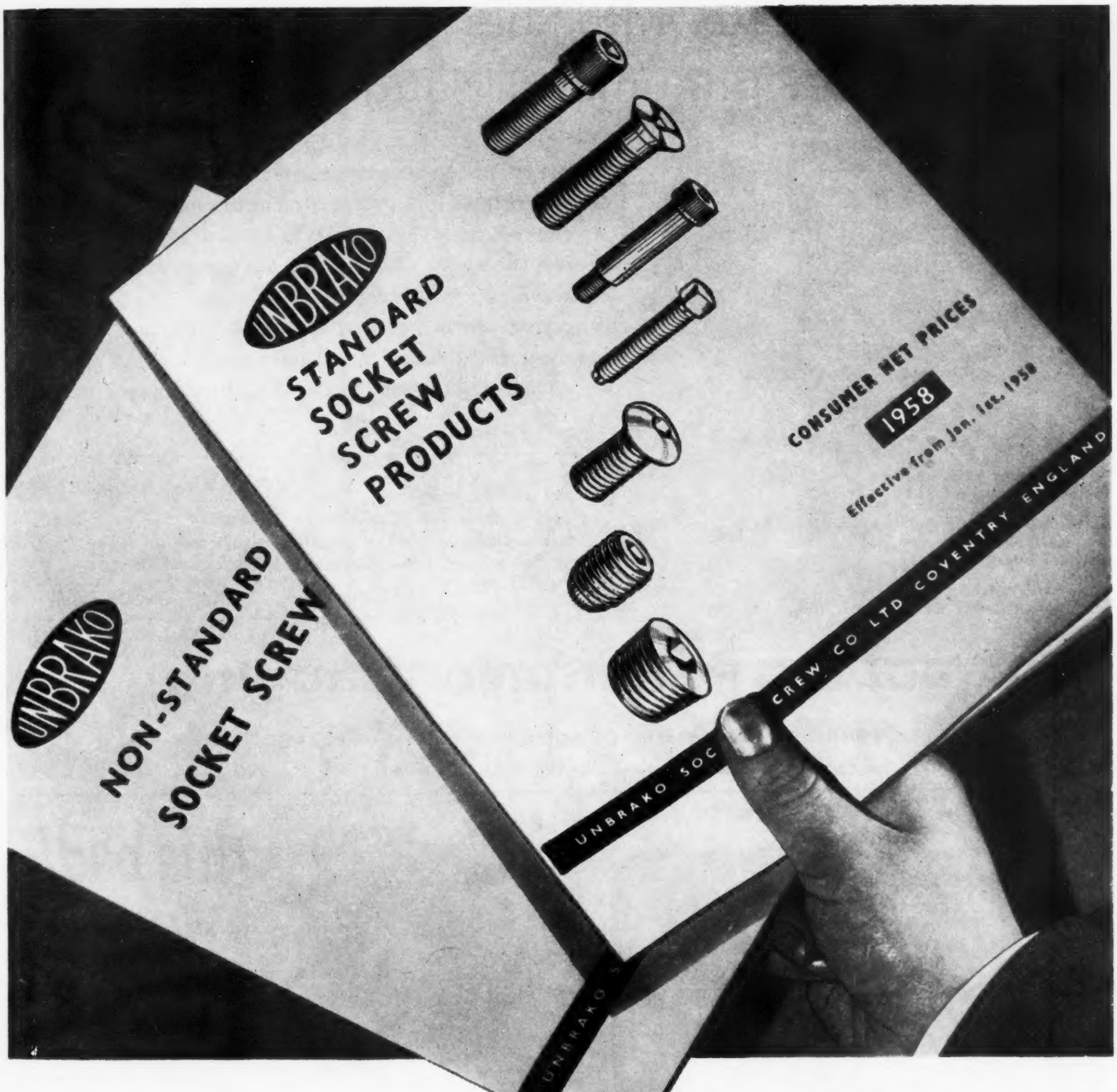

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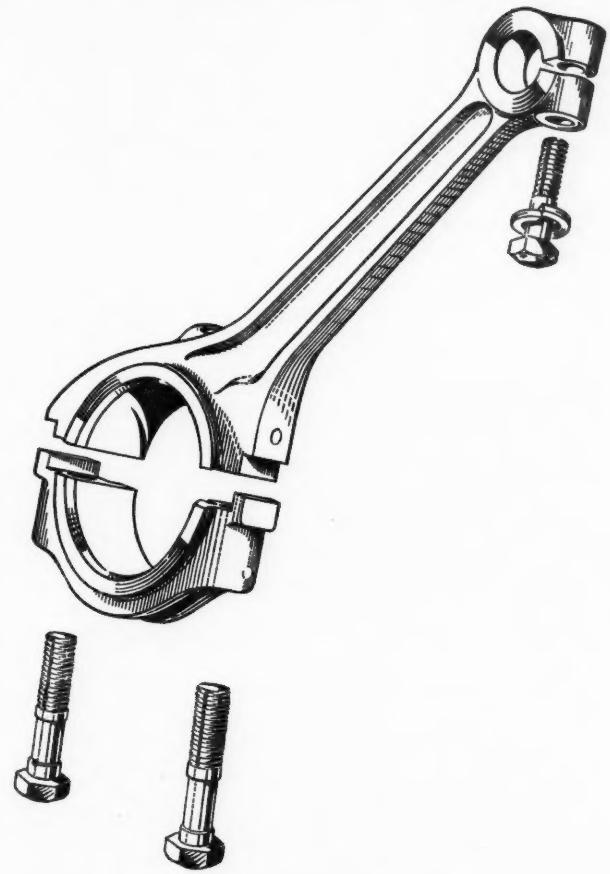

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